Continued from Supplement 1, Volume 1 (a)

Appendix E

Evaluation Process for Identifying the Environmental Impacts of Decommissioning Activities

Appendix E

Evaluation Process for Identifying the Environmental Impacts of Decommissioning Activities

This appendix describes the process that the staff used to determine the environmental impacts from decommissioning nuclear power facilities. Figure E-1 is a flowchart showing the evaluation process. The staff first created an initial list of environmental issues and decommissioning activities that this Supplement should address (Table E-1). The initial list of environmental issues was developed from the issues identified in the 1988 GEIS and the list specified in 10 CFR Part 51, Subpart A, Appendix B, for license renewal. The initial list of decommissioning activities was based on experience and the literature discussed in Section 3.2 of this Supplement. The staff used these initial lists of environmental issues and decommissioning activities for discussions during the scoping process (Section 1.3). At the conclusion of the scoping process and after conducting visits to six sites, the staff refined these two lists, based on comments from the public, the industry, the specific sites visited, the States, and other Federal agencies. During the scoping process, the staff visited the sites listed in Table E-2 and gathered information about the sites' decommissioning experiences. The sites were chosen to represent a variety of types of sites in various stages of decommissioning.

The staff designed a two-tier matrix system to document the evaluation process. In the Tier 1 (Table E-3) matrix, the environmental issues are listed on the horizontal axis and the decommissioning activities are listed on the vertical axis. Each activity in the list is grouped into broad categories designed to include a variety of specific activities. The list of activities is comprehensive and includes new technologies that were considered in this Supplement. Other innovative decommissioning options or activities not included in this document are expected to be developed by licensees in the future. Such options or activities do not fall under the conclusions of this Supplement and would need to be analyzed on a site-specific basis.

After compiling the environmental issue and decommissioning activity lists, the staff assessed which activities might have environmental impacts for each of the issues. The Tier 1 matrix (Table E-3) also shows the result of this evaluation. The Tier 1 matrix identifies impacts that occur for issues related to specific activities during the decommissioning process. In developing the Tier 1 matrix, the staff resolved whether the issue applies to the activity and whether there were potential environmental impacts. If the answer was "yes," the impacts in the matrix were marked with an "X" to designate the need for an analysis in the Supplement. For example, the transfer of the fuel from the reactor vessel to the spent fuel pool (an activity that occurs inside

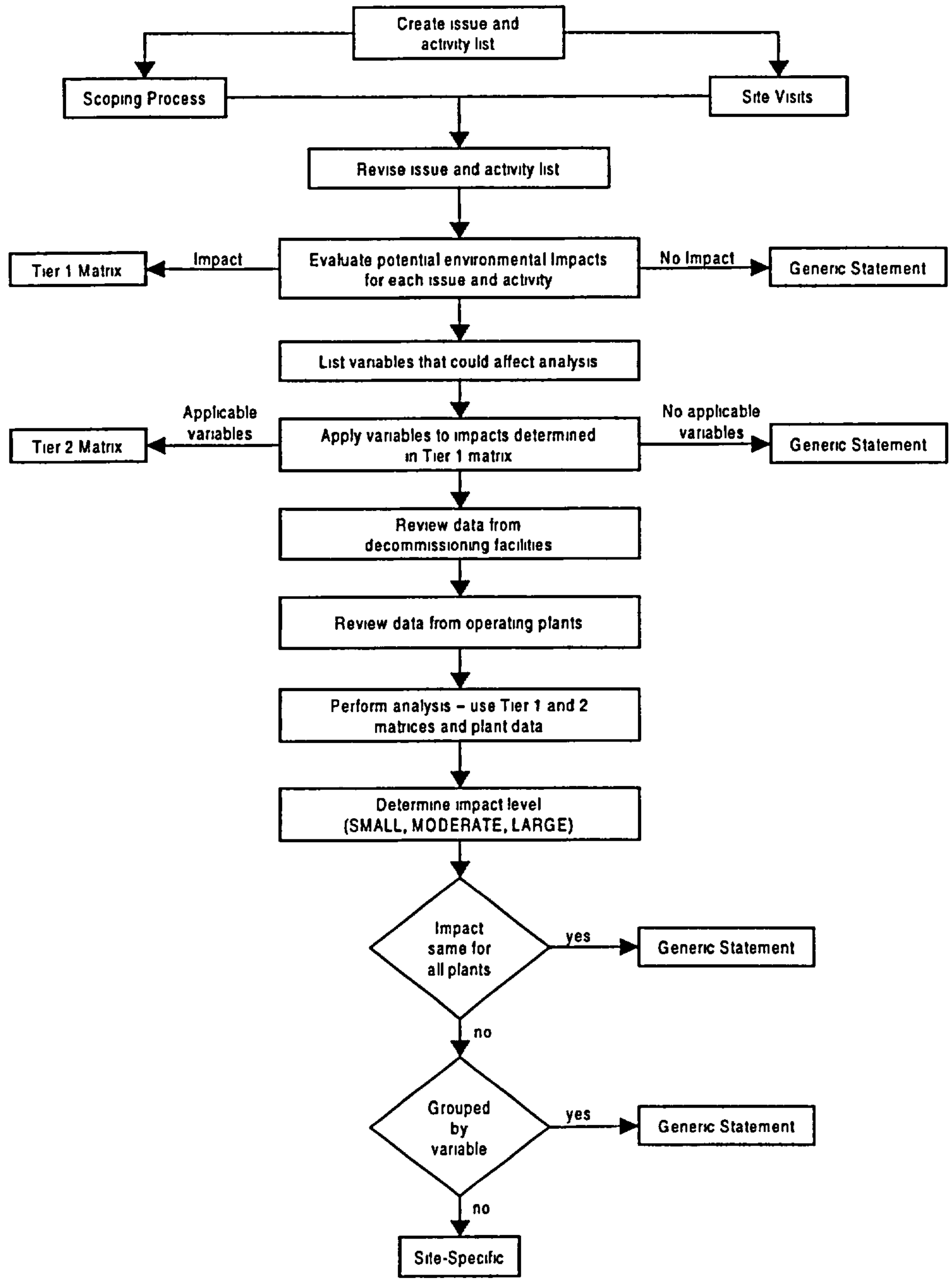

Figure E-1. Environmental Impact Evaluation Process

Table E-1. First- and Second-Tier Matrices Issues and Activities

Issues
Onsite/offsite land use
Water use
Water quality
Air quality
Aquatic ecology
Terrestrial ecology
Threatened and Endangered Species
Radiological
Radiological accidents
Occupational issues
Cost
Socioeconomics
Environmental justice
Cultural impacts
Aesthetic issues
Noise

Activities
Remove fuel
Organizational changes
Stabilization
Post-shutdown surveys
Create nuclear island
Chemical decontamination of primary loop
Large component removal
Storage preparation activities for SAFSTOR
Storage (SAFSTOR)
Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB1
System dismantlement
Structure dismantlement
Entombment
Low-level waste packaging and storage
Transportation
License termination activities

Table E-2. Site Visits

Nuclear Plant	Description	Plant Type	Thermal Power	Decommissioning Method
Big Rock Point	Single nuclear unit	BWR[(a)]	240 MW	DECON
Humboldt Bay, Unit 3	Single nuclear plant at multi-unit fossil fuel facility	BWR	200 MW	SAFSTOR
Maine Yankee	Single nuclear unit	PWR[(b)]	2700 MW	DECON
Rancho Seco	Single nuclear unit	PWR	2772 MW	SAFSTOR
Trojan	Single nuclear unit	PWR	3411 MW	DECON
Zion, Units 1 and 2	Multiple nuclear units	PWR	3250 MW	SAFSTOR

(a) boiling water reactor.
(b) pressurized water reactor.

the facility) would not result in aesthetic or noise issues. On the other hand, this activity would result in a radiation dose to the workers (radiological) and could potentially cause a radiological accident. In some cases, correlation between the activity and the issue was not evident. In these cases, the matrix was marked conservatively to ensure further analysis of the impact. This is the case with the issues of water use for the activity of transferring fuel to the spent fuel pool. The water that is used in this process is very small compared to the amount of water used to cool the reactor during operations. However, the matrix was marked to ensure that the water-use issue was addressed completely in this Supplement.

Typically, environmental impact statements would consider transportation as an issue and not as an activity. However, the staff determined that in the case of decommissioning nuclear power reactors, transportation is an activity, not an issue. Because there are several transportation-based impacts related to decommissioning nuclear power facilities, transportation was addressed in its own section (4.3.17) in this Supplement.

After completing the Tier 1 matrix, the next step was to identify the variables that might affect the environmental impact for a specific issue. These variables include some of the obvious differences between reactor facilities, such as whether the facility is a pressurized water reactor, boiling water reactor, or other type of reactor, whether it is a multi-unit site and what type of cooling system is used. The staff also considered variables that would impact a licensee's decision concerning types of activities or how an activity would be conducted. For example, the proximity of the facility to a barge slip or railroad might affect a licensee's decision to remove the steam generator or other large components intact and ship them to a waste site. If the barge slip needs additional dredging or an additional railroad line needs to be installed, then the environmental impacts may change. Table E-4 lists the variables, their abbreviations as they appear in the Tier 2 matrix (Table E-5), and the characteristics, if appropriate, for each variable.

The staff then considered each of the impact areas identified in the Tier 1 matrix, and determined if the variables influenced the environmental impacts. If no change would occur, then the "X" in the box was retained to signify that the variables do not change the analysis. If a change would occur, then the staff needs a second determination as to which variables could significantly change the impact. Variables that could significantly change the impact were listed by their abbreviation in the appropriate box in the matrix (see Table E-3 for the abbreviations). By resolving these questions, the staff developed the Tier 2 matrix shown in Table E-5. The staff used the Tier 2 matrix as the starting point for the analysis of the environmental impacts of the decommissioning activities for each of the applicable issues and variables.

The analyses that are presented in the following sections were based on the information in the Tier 2 matrix. The data used in the analyses was obtained from several sources:

- documents such as post-shutdown decommissioning activity reports, final environmental statements, environmental reports, and license termination plans for permanently shutdown and decommissioning facilities

- site visits

- information gathered from permanently shutdown and decommissioning facilities with the assistance of the Nuclear Energy Institute

- currently operating facilities (primarily from NUREG-1437 [NRC 1996]).

The analyses in this Supplement include data from both operating and decommissioning facilities in order to appropriately span the range of impacts so that future decommissioning facilities could consider using this Supplement. The data from the decommissioning facilities was used to determine whether an activity and associated issue could be considered generic. The reason for including the operating facilities is that they will eventually decommission. Also, many of the plants that have decommissioned were the smaller, older facilities.

E.1 References

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

Table E-3. Tier 1 Matrix - Decommissioning Activities and Issues

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
	Issues																
1. Remove Fuel																	
- Transfer fuel to spent fuel pool		X	X					X	X	X							
- Drain primary system			X					X	X	X	X						
- Process liquid			X					X	X	X	X						
2. Organizational Changes																	
- Reduce staff		X						X			X	X	X				
- Employ contractor or other additional staff		X		X				X			X	X	X				
- Adjust site training								X	X	X	X						
- Changes to licensing basis - site-specific											X						
3. Stabilization																	
- Drain and flush system			X	X				X	X	X	X						
- Isolate systems, structures, and components that are no longer required				X				X		X	X						
- Rewiring of site to eliminate unneeded electrical circuits						X	X	X		X	X			X			
4. Post-Shutdown Surveys																	
- Baseline surveys for the decontamination work								X			X						
- Continual surveys								X			X						
5. Create Nuclear Island																	
- Install electrical power supply to spent fuel pool								X		X	X						
- Reduce the security area to just that around the fuel											X						
- Change security function											X						

"X" indicates where there may be am impact from decommissioning activities.

Table E-3. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
- Install or modify chemistry controls										X							
- Move old or install new security-related equipment								X		X	X						
6. Chemical Decontamination of primary loop																	
- Cutting, chemicals in, chemicals out, cleanup/decon								X	X	X	X						
7. Large Component Removal																	
- Remove reactor vessel and internals intact or cut up	X	X				X	X	X	X	X	X			X			
- Steam generator and other large components removed intact or cut up	X					X	X	X	X	X	X			X			
8. Storage Preparation Activities for SAFSTOR																	
- Establish a reactor coolant system vent pathway				X				X		X	X						
- Establish containment vent pathway				X				X		X	X						
- De-energize systems, put in monitors where they are needed								X		X	X						
- Perform a radiological assessment								X			X						
9. Storage (SAFSTOR)																	
- Monitor systems and radiation levels etc.								X			X						
- Do preventive and corrective maintenance on SSCs								X		X	X						
- Maintain the security system											X						

"X" indicates where there may be an impact from decommissioning activities.

Table E-3. (contd)

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
	Issues																
- Maintain effluent and environmental monitoring programs				X							X						
10. Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB 1																	
- Chemical decontamination (surface/specific components)								X	X	X	X						
- Decontamination of piping inside walls								X	X	X	X						
- High-pressure water sprays of surface		X	X					X	X	X	X						
- Remove contaminated soil from specific areas						X	X	X		X	X			X			
- Do preventive and corrective maintenance on SSCs								X		X	X						
- Maintain the security system											X						
- Maintain effluent and environmental monitoring programs				X							X						
11. System Dismantlement																	
- Cut out radioactive piping								X	X	X	X						X
- Remove large and small tanks or other radioactive components from the facility								X	X	X	X						X
12. Structure Dismantlement																	
- Rubblization	X	X	X	X				X		X	X				X	X	X
- Remove structures that were necessary for plant operation	X	X		X	X	X	X	X	X	X	X				X	X	X

"X" indicates where there may be an impact from decommissioning activities.

Table E-3. (contd)

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
13. Entombment																	
- Install engineered barriers				X				X		X	X				X	X	
- Disconnect operational systems (e.g. electrical and fire protection)								X		X	X						
- Remove all radioactive material that is outside of containment								X		X	X					X	
- Place material inside containment								X		X	X						
- Lower containment ceiling (optional)		X		X				X	X	X	X						
- Entomb facility in concrete		X		X						X	X				X	X	
14. LLW packaging and storage	X							X	X	X	X						X
15. Transportation																	
- Large components				X				X	X	X	X		X				X
- LLW				X				X	X	X	X		X				X
- Equipment into site				X							X						
- Backfill trucked into site				X							X						X
- Nonradioactive waste				X							X						X
16. License Termination Activities																	
- Complete final radiation survey								X		X	X						
- Partial site release								X			X						

"X" indicates where there may be an impact from decommissioning activities.

Table E-4. Tier 2 Matrix Variables

Variable Abbreviation	Variable	Variable Characteristics
Type	Type of plant	PWR, BWR, HTGR, FBR
Size	Size of plant	Based on the facility thermal power capability
Loc	Population characteristics	Rural, urban
Env	Environmental features	Coastal, desert, lake, river shoreline, other
Cool Sys	Cooling system type	Closed cycle, once-through cooling
Cool	Cooling water source	Reservoir, lake, river or creek, ocean, canal, bay, pond, canal, sewage treatment plant
Grdwater	Groundwater usage/proximity to groundwater	
Fuel Loc	Fuel location - as a function of time	Spent fuel pool, ISFSI, away from reactor
Ops	Off-normal radiological operational events	Failed or leaking fuel, contaminated soil
Interim Time	Time between last shutdown and initiation of decommissioning	
Decom Opt	Decommissioning option	SAFSTOR, DECON, ENTOMB
Store Time	Duration of storage period for plants in deferred DECON/SAFSTOR	
Struct	Disposition of structures during decommissioning	Remain onsite, sent to a LLW site or vendor, entombed, landfill, rubblized
LLW	Distance traveled for disposal of LLW	
Gas Emissions	Method used to control gaseous radioactive effluents	
Land Mass	Land mass (footprint) of the site	
Culture	Cultural resources	Known/unknown, present/absent
Multi-Unit	Single unit versus multi-unit sites with other operating units	
Trans Prox	Proximity of barge/train transportation	

Table E-5. Tier 2 Matrix - Decommissioning Activities, Issues, and Variables

Activities	Issues																
	Onsite/Offsite Land Use	**Water Use**	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occupational Issues	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
1. Remove fuel																	
Transfer fuel to spent fuel pool		X	X					Ops; Interim Time	Ops; Interim Time	X							
Drain primary system			X					Ops; Interim Time; Decom Opt; Store Time	Ops; Interim Time; Decom Opt; Store Time	X	Interim Time; Decom Opt; Store Time						
Process liquid			X					Ops; Interim Time	Ops; Interim Time	X	Type; Size						
2. Organizational changes																	
Reduce staff		X						Type; Size			Type; Size; Decom Opt; Store Time	Size; Loc; Multi-Unit	Size; Loc; Multi-Unit				
Employ contractor or other additional staff		X		Size Loc; Decom Opt				Type; Size; Decom Opt; Store Time			Type; Size, Decom Opt; Store Time	Type; Size; Loc; Multi-Unit	Type; Size; Loc; Multi-Unit				

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Adjust site training								Type; Size; Decom Opt; Store Time	X	X	Type; Size; Decom Opt; Store Time						
Changes to licensing basis - site-specific											Type; Size; Decom Opt; Store Time						
3. Stabilization																	
Drain and flush system			X	X				Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Isolate systems, structures, and components that are no longer required				X				Type; Size; Ops; Interim Time; Decom Opt; Store Time		Type; Size, Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time						
Rewiring of site to eliminate unneeded electrical circuits						Loc; Env; Land Mass	Loc; Env; Land Mass	Type; Size; Ops; Interim Time; Decom Opt; Store Time		Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time			Loc; Land Mass			

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
4. Post-shutdown surveys																	
Baseline surveys for the decontamination work								Type; Size; Ops; Interim Time; Decom Opt; Land Mass			Type; Size; Ops; Interim Time; Decom Opt; Land Mass						
Continual surveys								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Land Mass			Type; Size; Ops; Interim Time; Decom Opt; Land Mass						
5. Create nuclear island																	
Install electrical power supply to spent fuel pool								Ops; Interim Time		Size	X						
Reduce the security area to just that around the fuel											X						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Change security function											X						
Install or modify chemistry controls										Size							
Move old or install new security-related equipment								Ops; Interim Time		Size, Land Mass	X						
6. Chemical decontamination of primary loop																	
Cutting, chemicals in, chemicals out, cleanup/ decontamination								Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
7. Large component removal																	
Remove reactor vessel and internals intact or cut up	Env; Land Mass	X				Trans Prox	Trans Prox	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type, Size, Ops; Interim Time, Decom Opt; Store Time	Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Trans Prox			Trans Prox			
Steam generator and other large components removed intact or cut up	Env; Land Mass					Trans Prox	Trans Prox	Type; Size, Ops; Interim Time; Decom Opt; Store Time	Type, Size, Ops; Interim Time; Decom Opt; Store Time	Type, Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Trans Prox			Trans Prox			

"X" indicates that none of the variables change the analysis

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
8. Storage preparation activities for SAFSTOR																	
Establish a reactor coolant system vent pathway				Gas Emissions				Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time						
Establish containment vent pathway				Gas Emissions				Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time						
De-energize systems, put in monitors where they are needed								Type; Size; Ops; Interim Time; Store Time		Type; Size	Type; Size; Ops; Interim Time; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Perform a radiological asessment								Type; Size; Ops; Interim Time; Store Time			Type; Size; Ops; Interim Time; Store Time						
9. Storage (SAFSTOR)																	
Monitor systems and radiation levels, etc.								Type; Size, Interim Time; Store Time		Type, Size; Store Time	Type, Size; Store Time						
Do preventive and corrective maintenance on SSCs								Type; Size, Interim Time; Store Time			Type; Size; Store Time						
Maintain the security system											Store Time; Multi-Unit						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Maintain effluent and environmental monitoring programs				Gas Emissions							Store Time; Multi-Unit						
10. Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB1																	
Chemical decontamination (surface/specific components)								Type; Size; Ops, Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time	Type; Size	Type; Size; Ops; Interim Time; Store Time						
Decontamination of piping inside walls								Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time	Type; Size	Type; Size; Ops; Interim Time; Store Time						
High-pressure water sprays of surface		X	X					Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Remove contaminated soil from specific areas						Loc; Env, Land Mass	Loc; Env; Land Mass	Type; Size; Ops; Interim Time; Store Time		Type; Size	Type; Size; Ops; Interim Time; Store Time			Loc; Land Mass			
Do preventive and corrective maintenance on SSCs								Type; Size; Ops; Interim Time; Store Time		Type, Size	Type; Size; Ops; Interim Time; Store Time						
Maintain the security system											Type; Multi-Unit						
Maintain effluent and environmental monitoring programs				Gas Emissions							Type; Multi-Unit						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
11. System dismantlement																	
Cut out radioactive piping								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct						
Remove large and small tanks or other radioactive components from the facility								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
12. Structure Dismantlement																	
Rubblization	Size	Size	Grd-water	Size; Loc; Land Mass				Type; Size; Loc; Ops; Interim Time; Decom Opt; Store Time		X	Size				X	X	X
Remove structures that are necessary for plant operation	Size; Loc; Land Mass	Size; Struct		Type, Size; Struct	Size; Loc	Size, Loc	Size, Loc	Type; Size; Loc; Ops; Interim Time, Decom Opt; Store Time	Type; Size; Loc; Ops; Interim Time; Decom Opt; Store Time	Size; Decom Opt; Land Mass	Type; Size, Loc; Ops; Interim Time, Decom Opt; Store Time				Size, Loc	Size; Loc	Size; Decom Opt

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
13. Entombment																	
Install engineered barriers				Size				Size		X	Size				X	X	
Disconnect operational systems (e g., electrical and fire protection)								Size		X	Size						
Remove all radioactive material that is outside of containment								Type; Size		X	Type; Size					Type; Size; Land Mass	
Place material inside containment										X	Size						
Lower containment ceiling (optional)		X		Type; Size				Type; Size; Ops; Interim Time	Type; Size; Ops; Interim Time	X	Size						
ENTOMB facility in concrete		X		Type; Size				Type; Size; Ops; Interim Time		X	Size				X	X	

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
14. LLW packaging and storage and disposal	X							Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type, Size; Ops; Interim Time; Decom Opt, Store Time	Type; Size; Ops, Interim Time; Decom Opt; Store Time						Type; Size; Ops; Interim Time; Decom Opt; Store Time
15. Transportation																	
Large components				Size; Loc; Env; Decom Opt				LLW; Trans Prox	LLW; Trans Prox	X	LLW; Trans Prox		LLW; Trans Prox				X
LLW				Trans Prox; Size; Loc; Env; Decom Opt; LLW				LLW	LLW	X	LLW		Size; Loc; Env				X

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																	
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Equipment into site				Decom Opt; Trans Prox							Trans Prox						
Backfill trucked into site				Size; Decom Opt							Size; Decom Opt; Land Mass; Trans Prox						X
Nonradioactive waste				Size; Loc; Env; Struct; Decom Opt, Trans Prox							Type; Size; Decom Opt						X

Table E-5. (contd)

16. License Termination Activities																	
Complete final radiation survey								X		X	Size; Type; Decom Opt; Land Mass						
Partial site release								X			Loc; Env; Struct, Land Mass; Culture						

"X" indicates that none of the variables change the analysis.

Appendix F

Summary Table of Permanently Shutdown and Currently Operating Commercial Nuclear Reactors

Table F-1. Permanently Shutdown Commercial Nuclear Plants

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that are Currently in the Process of Decommissioning										
Big Rock Point	Michigan	BWR	240 MW	DECON	593	OT	Lake Michigan	Fuel in pool	05/01/1964	08/30/1997
Dresden, Unit 1	Illinois	BWR	700 MW	SAFSTOR	953+1274 cooling pond	Cooling lake and spray system	Kankakee River	Fuel in onsite ISFSI	09/28/1959	10/31/1978
Fermi, Unit 1	Michigan	FBR	200 MW	SAFSTOR	900[d]	OT	Lake Erie	No fuel onsite	05/01/1963	09/22/1972
GE-VBWR	California	BWR	50 MW	SAFSTOR	~1[e]	MDCI	Onsite cooling pond	No fuel onsite	05/14/1956	12/09/1963
Haddam Neck	Connecticut	PWR	1825 MW	DECON	524	OT	Connecticut River	Fuel in pool	12/27/1974	07/22/1996
Humboldt Bay, Unit 3	California	BWR	200 MW	SAFSTOR	143	OT	Humboldt Bay	Fuel in pool	08/28/1962	07/02/1976
Indian Point, Unit 1	New York	PWR	615 MW	SAFSTOR	239	OT	Hudson River	Fuel in pool	03/26/1962	10/31/1974
La Crosse	Wisconsin	BWR	165 MW	SAFSTOR	163[f]	FCDC	Mississippi River	Fuel in pool	07/03/1967	04/30/1987
Maine Yankee	Maine	PWR	2700 MW	DECON	820	OT	Montsweag Bay	Fuel in pool	06/29/1973	12/06/1996
Millstone, Unit 1	Connecticut	BWR	2011 MW	SAFSTOR	500	OT	Long Island Sound	Fuel in pool	10/07/1970	11/04/1995
Peach Bottom, Unit 1	Pennsylvania	HTGR	115 MW	SAFSTOR	620[g]	OT	NA	No fuel onsite	06/01/1967	10/31/1974

Table F-1. (contd)

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that are Currently in the Process of Decommissioning (contd)										
Rancho Seco	California	PWR	2772 MW	SAFSTOR/ incremental decom	2480	NDCT	Folsom Canal	Fuel in onsite ISFSI/ DECON proposed in 1997	08/16/1974	06/07/1989
San Onofre, Unit 1	California	PWR	1347 MW	SAFSTOR	84	OT	Pacific Ocean	Fuel in pool	03/27/1967	11/30/1992
Saxton	Pennsylvania	PWR	28 MW	SAFSTOR	~1.1[h]	OT[i]	Juniata River	No fuel onsite/ currently in DECON	11/15/1961	05/01/1972
Three Mile Island, Unit 2	Pennsylvania	PWR	2772 MW	Accident cleanup followed by storage	472	NDCT	Susquehanna River	Approx 900 kg fuel onsite/ Post-Defueling Monitored Storage	02/08/1978	03/28/1979
Trojan	Oregon	PWR	3411 MW	DECON	635	NDCT	Columbia River	Fuel in pool	11/21/1975	11/09/1992
Yankee Rowe	Massachusetts	PWR	600 MW	DECON	1997	OT	Deerfield River	Fuel in pool[j]	12/24/1963	10/01/1991
Zion, Unit 1	Illinois	PWR	3250 MW	SAFSTOR	250	OT	Lake Michigan	Fuel in pool	10/19/1973	02/21/1997
Zion, Unit 2	Illinois	PWR	3250 MW	SAFSTOR	250	OT	Lake Michigan	Fuel in pool	11/14/1973	09/19/1996

Table F-1. (contd)

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that have had their Licenses Terminated										
Fort St. Vrain	Colorado	HTGR	842 MW	DECON	2798	OT	NA	Fuel in ISFSI/ License terminated in 1997	12/01/1976	08/18/19891
Pathfinder	South Dakota	BWR	190 MW	SAFSTOR	1200	MDCT	Big Sioux River	No fuel onsite/ License terminated in 1992	01/01/1964	09/16/1967
Shoreham	New York	BWR	2436 MW	DECON	499	OT	Long Island Sound	No fuel onsite/ License terminated in 1995	06/01/1985	06/28/1989

(a) The option shown in the table for each plant is the option that has been officially provided to NRC. Plants in DECON may have had a short (1 to 4 yr) SAFSTOR period. Likewise, plants in SAFSTOR may have performed some DECON activities or may have transitioned from the storage phase into the decontamination and dismantlement phase of SAFSTOR.
(b) OT = once through; NDCT = natural draft cooling tower; FCDC = forced-circulation, direct cycle; MDCT - Mechanical Draft Cooling Tower; NA = not applicable.
(c) The shutdown date corresponds to the date of the last criticality.
(d) Originally licensed site area for Fermi, Unit 1. Currently, the facility occupies an area of less than 1.6 ha (4 ac) on the Fermi, Unit 2, site.
(e) The reactor building and associated structures occupy approximately 0 4 ha (1 ac) in the approximately 640 ha (1600 ac) Vallicitos Nuclear Center.
(f) The La Crosse site area is approximately 1 2 ha (3 ac) with the total utility-owned area being 66 ha (163 ac).
(g) Peach Bottom site area includes all units (1, 2, and 3).
(h) Originally licensed site area for the Saxton Plant was 0.4 ha (1.1 ac), wholly contained in a utility-owned property of approximately 61 ha (150 ac).
(i) Once-through cooling combined with a fossil steam electric generating facility also using spray pond during periods of high ambient temperatures.
(j) License is in process of transferring fuel to dry storage in onsite ISFSI.

Table F-2. Currently Operating Commercial Nuclear Plants

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
Arkansas Nuclear One	1	Arkansas	PWR	2568 MW	1160	OT	Dardanelle Reservoir	05/21/1974	05/20/2034[d]
Arkansas Nuclear One	2	Arkansas	PWR	2815 MW	1160	NDCT	Dardanelle Reservoir	09/01/1978	07/17/2018
Beaver Valley	1	Pennsylvania	PWR	2652 MW	501	NDCT	Ohio River	07/02/1976	01/29/2016
Beaver Valley	2	Pennsylvania	PWR	2652 MW	501	NDCT	Ohio River	08/14/1987	05/27/2027
Braidwood	1	Illinois	PWR	3411 MW	4457	CCCP	Kankakee River	07/02/1987	10/17/2026
Braidwood	2	Illinois	PWR	3411 MW	4457	CCCP	Kankakee River	05/20/1988	12/18/2027
Browns Ferry	1	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	12/20/1973	12/20/2013
Browns Ferry	2	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	08/02/1974	06/28/2014
Browns Ferry	3	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	08/18/1976	07/02/2016
Brunswick	1	North Carolina	BWR	2558 MW	1210	OT	Cape Fear River	11/12/1976	09/08/2016
Brunswick	2	North Carolina	BWR	2436 MW	1210	OT	Cape Fear River	12/27/1974	12/27/2014
Byron	1	Illinois	PWR	3411 MW	1398	NDCT	Rock River	02/14/1985	10/31/2024
Byron	2	Illinois	PWR	3411 MW	1398	NDCT	Rock River	01/30/1987	11/06/2026
Callaway		Missouri	PWR	3565 MW	3188	NDCT	Missouri River	10/18/1984	10/18/2024
Calvert Cliffs	1	Maryland	PWR	2700 MW	1135	OT	Chesapeake Bay	07/31/1974	07/31/2034[d]
Calvert Cliffs	2	Maryland	PWR	2700 MW	1135	OT	Chesapeake Bay	11/30/1976	08/31/2036[d]
Catawba	1	South Carolina	PWR	3411 MW	391	MDCT	Lake Wylie	01/17/1985	12/06/2024
Catawba	2	South Carolina	PWR	3411 MW	391	MDCT	Lake Wylie	05/15/1986	02/24/2026
Clinton		Illinois	BWR	2894 MW	14090	OT	Salt Creek	04/17/1987	09/29/2026
Columbia Generating Station		Washington	BWR	3486 MW	DOE, Hanford Reservation	MDCT	Columbia River	04/13/1984	12/20/2023
Comanche Peak	1	Texas	PWR	3411 MW	7669	OT	Squaw Creek Reservoir	04/17/1990	02/08/2030
Comanche Peak	2	Texas	PWR	3411 MW	7669	OT	Squaw Creek Reservoir	04/06/1993	02/02/2033
Cooper		Nebraska	BWR	2381 MW	1090	OT	Missouri River	01/18/1974	01/18/2014
Crystal River	3	Florida	PWR	2544 MW	4738	OT	Gulf of Mexico	01/28/1977	12/03/2016
Davis Besse		Ohio	PWR	2772 MW	954	NDCT	Lake Erie	04/22/1977	04/22/2017
Diablo Canyon	1	California	PWR	3338 MW	741	OT	Pacific Ocean	11/02/1984	09/22/2021
Diablo Canyon	2	California	PWR	3411 MW	741	OT	Pacific Ocean	08/26/1985	04/26/2025
Donald C. Cook	1	Michigan	PWR	3250 MW	642	OT	Lake Michigan	10/25/1974	10/25/2014
Donald C. Cook	2	Michigan	PWR	3411 MW	642	OT	Lake Michigan	12/23/1977	12/23/2017
Dresden	2	Illinois	BWR	2527 MW	953+1274 Cooling pond	Cooling lake and spray canal	Kankakee	02/20/1991	01/10/2006
Dresden	3	Illinois	BWR	2527 MW	953+1274 Cooling pond	Cooling lake and spray canal	Kankakee	03/02/1971	01/12/2011
Edwin I Hatch	1	Georgia	BWR	2558 MW	2244	MDCT	Altamaha River	10/13/1974	08/06/2034
Edwin I Hatch	2	Georgia	BWR	2558 MW	2244	MDCT	Altamaha River	06/13/1978	06/13/2038
Fermi	2	Michigan	BWR	3430 MW	1120	NDCT	Lake Erie	07/15/1985	03/20/2025
Fort Calhoun	1	Nebraska	PWR	1500 MW	667	OT	Missouri River	08/09/1973	08/09/2013
Ginna	1	New York	PWR	1520 MW	338	OT	Lake Ontario	12/10/1984	09/18/2009
Grand Gulf	1	Mississippi	BWR	3833 MW	2100	NDCT	Mississippi River	11/01/1984	06/16/2022

Table F-2. (contd)

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
H B. Robinson	2	South Carolina	PWR	2300 MW	4942	OT	Lake Robinson	09/23/1970	07/31/2010
Hope Creek	1	Delaware	BWR	3293 MW	740	NDCT	Delaware River	07/25/1986	04/11/2026
Indian Point	2	New York	PWR	3071 MW	239	OT	Hudson River	09/28/1973	09/28/2013
Indian Point	3	New York	PWR	3025 MW	239	OT	Hudson River	04/05/1976	12/15/2015
James A. Fitzpatrick		New York	BWR	2536 MW	702	OT	Lake Ontario	10/17/1974	10/17/2014
Joseph M. Farley	1	Alabama	PWR	2775 MW	1850	MDCT	Chattahochee River	06/25/1977	06/25/2017
Joseph M. Farley	2	Alabama	PWR	2775 MW	1850	MDCT	Chattahochee River	03/31/1981	03/31/2021
Kewaunee		Wisconsin	PWR	1650 MW	908	OT	Lake Michigan	12/21/1973	12/21/2013
La Salle	1	Illinois	BWR	3323 MW	3064	Cooling pond	Illinois River	08/13/1982	05/17/2022
La Salle	2	Illinois	BWR	3323 MW	3064	Cooling pond	Illinois River	03/23/1984	12/16/2023
Limerick	1	Pennsylvania	BWR	3458 MW	595	NDCT	Schuylkill River	08/08/1985	10/26/2024
Limerick	2	Pennsylvania	BWR	3458 MW	595	NDCT	Schuylkill River	08/25/1989	06/22/2029
McGuire	1	North Carolina	PWR	3411 MW	577	OT	Lake Norman	07/08/1981	06/12/2021
McGuire	2	North Carolina	PWR	3411 MW	577	OT	Lake Norman	05/27/1983	03/03/2023
Millstone	2	Connecticut	PWR	2700 MW	494	OT	Long Island Sound	09/26/1975	07/31/2015
Millstone	3	Connecticut	PWR	3411 MW	494	OT	Long Island Sound	01/31/1986	11/25/2025
Monticello		Minnesota	BWR	1670 MW	2125	OT with towers	Mississippi River	01/09/1981	09/08/2010
Nine Mile Point	1	New York	BWR	1850 MW	890	OT	Lake Ontario	12/26/1974	08/22/2009
Nine Mile Point	2	New York	BWR	3467 MW	890	NDCT	Lake Ontario	07/02/1987	10/31/2026
North Anna	1	Virginia	PWR	2893 MW	1043	OT	Lake Anna	04/01/1978	04/01/2018
North Anna	2	Virginia	PWR	2893 MW	1043	OT	Lake Anna	08/21/1980	08/21/2020
Oconee	1	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	02/06/1973	02/06/2033[d]
Oconee	2	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	10/06/1973	10/06/2033[d]
Oconee	3	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	07/19/1974	07/19/2034[d]
Oyster Creek	1	New Jersey	BWR	1930 MW	1416	OT	Barnegat Bay	04/09/1969	12/15/2009
Palisades	1	Michigan	PWR	2530 MW	487	MDCT	Lake Michigan	03/24/1971	03/14/2007
Palo Verde	1	Arizona	PWR	3800 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	06/01/1985	12/31/2024
Palo Verde	2	Arizona	PWR	3876 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	04/24/1986	12/09/2025
Palo Verde	3	Arizona	PWR	3876 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	11/25/1987	03/25/2027
Peach Bottom	2	Pennsylvania	BWR	3458 MW	620	OT with towers	Conowingo Pond	12/14/1973	08/08/2013
Peach Bottom	3	Pennsylvania	BWR	3458 MW	620	OT with towers	Conowingo Pond	07/02/1974	07/02/2014
Perry	1	Ohio	BWR	3579 MW	1112	NDCT	Lake Erie	11/13/1986	03/18/2026
Pilgrim	1	Massachusetts	BWR	1998 MW	517	OT	Cape Cod Bay	09/15/1972	06/08/2012
Point Beach	1	Wisconsin	PWR	1519 MW	2065	OT	Lake Michigan	10/05/1970	10/05/2010
Point Beach	2	Wisconsin	PWR	1519 MW	2065	OT	Lake Michigan	03/08/1973	03/08/2013
Prairie Island	1	Minnesota	PWR	1650 MW	568	MDCT or OT	Mississippi River	04/05/1974	08/09/2013
Prairie Island	2	Minnesota	PWR	1650 MW	568	MDCT or OT	Mississippi River	10/29/1974	10/29/2014

Table F-2. (contd)

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
Quad Cities	1	Illinois	BWR	2511 MW	784	OT	Mississippi River	12/14/1972	12/14/2012
Quad Cities	2	Illinois	BWR	2511 MW	784	OT	Mississippi River	12/14/1972	12/14/2012
River Bend	1	Louisiana	BWR	2894 MW	3342	MDCT	Mississippi River	11/20/1985	08/29/2025
Salem	1	New Jersey	PWR	3411 MW	691	OT	Delaware River	12/01/1976	08/13/2016
Salem	2	New Jersey	PWR	3411 MW	691	OT	Delaware River	05/20/1981	04/18/2020
San Onofre	2	California	PWR	3390 MW	84	OT	Pacific Ocean	09/07/1982	10/18/2013
San Onofre	3	California	PWR	3390 MW	84	OT	Pacific Ocean	09/16/1983	10/18/2013
Seabrook	1	New Hampshire	PWR	3411 MW	896	OT	Atlantic Ocean	03/15/1990	10/17/2026
Sequoyah	1	Tennessee	PWR	3411 MW	525	OT and/or NDCT	Chickamauga Lake	09/17/1980	09/17/2020
Sequoyah	2	Tennessee	PWR	3411 MW	525	OT and/or NDCT	Chickamauga Lake	09/15/1981	09/15/2021
Shearon Harris	1	North Carolina	PWR	2775 MW	10744	NDCT	Buckhorn Creek	01/12/1987	10/24/2026
South Texas	1	Texas	PWR	3800 MW	12350	CCCP	Colorado River	03/22/1988	08/20/2027
South Texas	2	Texas	PWR	3800 MW	12350	CCCP	Colorado River	03/28/1989	12/15/2028
St. Lucie	1	Florida	PWR	2700 MW	1132	OT	Atlantic Ocean	03/01/1976	03/01/2016
St. Lucie	2	Florida	PWR	2700 MW	1132	OT	Atlantic Ocean	06/10/1983	04/06/2023
Summer	1	South Carolina	PWR	2900 MW	2200	OT	Lake Monticello	11/12/1982	08/06/2022
Surry	1	Virginia	PWR	2546 MW	840	OT	James River	05/25/1972	05/25/2012
Surry	2	Virginia	PWR	2546 MW	840	OT	James River	01/29/1973	01/29/2013
Susquehanna	1	Pennsylvania	BWR	3441 MW	1075	NDCT	Susquehanna River	11/12/1982	07/17/2022
Susquehanna	2	Pennsylvania	BWR	3441 MW	1075	NDCT	Susquehanna River	06/27/1984	03/23/2024
Three Mile Island	1	Pennsylvania	PWR	2568 MW	472	NDCT	Susquehanna River	04/19/1974	04/19/2014
Turkey Point	3	Florida	PWR	2300 MW	23970	Closed cycle canal	Biscane Bay	07/19/1972	07/19/2032
Turkey Point	4	Florida	PWR	2300 MW	23970	Closed cycle canal	Biscane Bay	04/10/1973	04/10/2033
Vermont Yankee	1	Vermont	BWR	1593 MW	125	OT and towers	Connecticut River	02/28/1973	03/21/2012
Vogtle	1	Georgia	PWR	3565 MW	3169	NDCT	Savannah River	03/16/1987	01/16/2027
Vogtle	2	Georgia	PWR	3565 MW	3169	NDCT	Savannah River	03/31/1989	02/09/2029
Waterford	3	Louisiana	PWR	3390 MW	3561	OT	Mississippi	03/16/1985	12/18/2024
Watts Bar	1	Tennessee	PWR	3411 MW	1769	NDCT	Chickamauga Lake	02/07/1996	11/09/2035
Wolf Creek	1	Kansas	PWR	3565 MW	9818	CCCP	Wolf Creek	06/04/1985	03/11/2025

(a) Licensees may seek power uprates
(b) OT = once-through, NDCT = natural draft cooling towers; CCCP = closed-cycle cooling pond, MDCT = mechanical draft cooling towers.
(c) Licensees may seek a renewal of the license
(d) Includes 20-year license renewal period

Appendix G

Radiation Protection Considerations for Nuclear Power Facility Decommissioning

Appendix G

Radiation Protection Considerations for Nuclear Power Facility Decommissioning

Radiological issues are associated with the process of decommissioning nuclear reactor facilities, including power reactors, at the end of their operating lives. Both occupational workers and members of the public will be affected by these processes as a result of direct exposures to sources of radiation and as a result of small releases of radioactive materials in gaseous and liquid effluents. This appendix is intended to provide pertinent background information for analyses in this Generic Environmental Impact Statement Supplement.

G.1 Radiation Protection Standards

The primary U.S. Nuclear Regulatory Commission (NRC) standards for protection of workers and members of the public are found in 10 CFR Part 20. These standards are consistent with guidance to Federal agencies prepared by interagency committees and issued by the President. The Federal guidance is based on recommendations published by national and international organizations, such as the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation. Proposed changes to regulations are typically published in the Federal Register for public comment before enactment of the final rule. The most recent major revision to the NRC radiation protection regulations in 10 CFR Part 20 were enacted in 1991, with several amendments issued in the intervening years. Implementation of the regulations became mandatory for NRC licensees in 1994.

G.1.1 Concepts, Terminology, Quantities, and Units Used in Radiation Protection

Title 10 CFR Part 20 was first promulgated in 1957. In 1961, the regulation was amended to add an appendix containing maximum permissible concentrations and a new occupational dose limit structure for whole-body exposure to external radiation (1.25 rem/quarter, or 3 rem/quarter with 5 rem/yr average as a limit on the cumulative dose). The 1991 revision differs considerably from the previous regulations with respect to basic concepts, terminology, radiation dose quantities, and the associated dose units. This section is included to familiarize readers with these concepts.

G.1.1.1 Conventional Quantities and Units

In 10 CFR Part 20, the unit "rad" is usually used for the quantity "radiation absorbed dose" whenever early biological effects are the concern. When latent effects (e.g., cancer and genetic effects) are being considered, the unit "rem" is used for the dose equivalent (DE) quantity. The absorbed dose in rads is multiplied by an overall efficiency factor *Q* to obtain the DE in rem. Each type of radiation has its own value of *Q*, which in a very general way permits adding absorbed doses from different radiations to estimate the probability of stochastic effects. Values of Q in 10 CFR Part 20 are indicated in Table G-1.

Table G-1. Quality Factors and Absorbed Equivalents

Radiation	Absorbed Dose, rad	Q	Dose Equivalent, rem
x -, gamma or beta radiation	1	1	1
Alpha particles	1	20	20
Neutron (spectrum unknown)	1	10	10

Note: To convert rem to sievert, multiply by 0.01.

These values of *Q* reflect the overall efficiency of a given type of radiation in causing latent effects and are not used for early effects such as acute radiation syndrome. The values were derived in consideration of the ability of the various radiations to ionize atoms in water as well as the relative biological effectiveness factors observed for specific effects.

G.1.1.2 International System of Units

The International System (SI) units of particular interest in radiation protection are the gray (Gy), sievert (Sv), and becquerel (Bq), as shown in Table G-2. The SI units are part of the metric system; however, they are not yet widely used in the United States.
Title 10 CFR 20.2101 requires the records to be reported in the units of curie, rad, and rem. The major concern of the NRC staff is that use of both the conventional and SI units would introduce confusion under emergency conditions.

Table G-2. Conventional and SI Units

Quantity	Conventional Unit	SI Unit	SI Unit Conversions
Absorbed dose	rad (100 ergs/gram)	gray (Gy) (10,000 ergs/gram)	100 rad = 1 Gy
Dose equivalent	rem (Q x rad)	sievert (Sv) (Q x gray)	100 rem = 1 Sv
Activity	curie (Ci) (3.7 x 10^{10} disintegrations per second)	becquerel (Bq) (1 disintegration per second)	1 Ci = 3.7 x $10^{(10)}$ Bq

G.1.1.3 Collective Dose

Previous revisions of 10 CFR Part 20 made no use of the collective DE (in person-rem). However, this quantity is used by the NRC in risk analyses and in its decision-making processes. The collective DE may be obtained as the sum of all individual doses or as the product of the average individual dose and the number of people exposed. The linear-nonthreshold hypothesis is accepted by the NRC for purposes of standards setting. Such acceptance means that standards based on the hypothesis, coupled with the "as low as reasonably achievable" (ALARA) concept, are believed to provide an adequate degree of protection.

G.1.1.4 Risks from Radiation Exposure

The current regulations in 10 CFR Part 20 are based on concepts first developed by the ICRP in Publication 26 (ICRP 1977). The ICRP system is based on the recognition of two basic types of radiation-induced health effects: stochastic and nonstochastic. Stochastic effects, such as cancer and hereditary effects, are considered to be probabilistic in nature. For stochastic effects, the probability of the effect, but not the severity, is dose-dependent (i.e., once a malignancy occurs). Its severity is no different if the dose that preceded it were 1 Sv (100 rem), 0.1 Sv (10 rem), or zero. The objective of radiation protection policies is to control the probability of these effects to acceptable levels. In contrast, the severity of nonstochastic effects, but not the probability of occurrence, depends on the radiation dose. Examples of radiation-induced nonstochastic effects include cataracts in the lens of the eye or burns on the skin surface. Nonstochastic effects typically do not occur unless the dose exceeds a threshold, which is specific to each type of effect. Once the threshold dose is exceeded, the effect occurs, and the severity of the effect depends on the dose received by the affected tissue or organ. For example, a radiation-induced cataract caused by a 4-Sv (400-rem) dose to the lens of the eye would impair vision to a greater extent than one following a dose of 1 Sv (100 rem). Therefore, radiation protection for nonstochastic effects is designed to keep radiological exposures to sensitive tissues below the threshold levels at which the effects would begin to appear.

In January 1990, the National Research Council (NAS 1990) published a report on the health effects of exposure to low levels of ionizing radiation. This report was prepared by the Committee on Biological Effects of Ionizing Radiation (BEIR) known as the BEIR-V Committee, organized by the Council for this purpose. The BEIR-V report concluded that the risk of radiation exposure was greater than estimates published by previous committees (NAS 1972, NAS 1980). In light of this data, the ICRP requested comment from a number of organizations on a draft of its revised recommendations on radiation protection. In 1991, the ICRP issued Publication 60 (ICRP 1991) recommending lower limits for occupational exposures. With regard to this Supplement, the primary importance of these developments lies in the selection of the most appropriate radiation risk coefficients to use for evaluating health effects. For a more complete history of the development of radiological risk estimates, see NRC (1996), Appendix E.

G.1.1.4.1 Stochastic Effects

Stochastic effects refer to health effects, such as cancer and inheritable genetic effects, for which the probability of occurrence is related to radiation dose. Based on the BEIR-V study (1990), the risks were estimated as 4 to 5 excess cancer deaths among 10,000 people receiving 100 person-Sv (10,000 person-rem). The following statement appears in the executive summary of the BEIR-V report (NAS 1990, p. 6):

> On the basis of the available evidence, the population-weighted average lifetime excess risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv [0.1 Gy of low-linear energy transfer (LET) radiation] is estimated to be 0.8 percent, although the lifetime risk varies considerably with age at the time of exposure. For low-LET radiation, accumulation of the same dose over weeks or months, however, is expected to reduce the lifetime risk appreciably, possibly by a factor of 2 or more.

The 0.8-percent estimate is equivalent to 800 excess cancer fatalities among 100,000 people, each exposed to 0.1 Sv (10 rem). It is important to note that the risk values tabulated in the report are for a population size of 100,000 and that the 0.8-percent estimate is applicable to instantaneous, uniform irradiation of all organs. With regard to the lower extreme of the dose range over which the estimate is applicable, the Committee observes elsewhere in the BEIR-V report that "in general, the estimates of risk derived in this way for doses of less than 0.1 Gy (10 rem) are too small to be detectable by direct observation in epidemiological studies." The report does not provide a risk estimate for instantaneous doses of fewer than 0.1 Sv (10 rem). The Committee's estimate is considered useful for estimating fatalities among large populations, including all ages, that are irradiated instantaneously and uniformly to individual external radiation doses of 0.1 Sv (10 rem) or more. Risk assessments based on the Japanese experience are subject to substantially greater uncertainty when applied to conditions typically encountered in environmental exposures from normal facility operations, where

- exposures are protracted
- the exposed population is small
- individual doses are much lower than 0.1Sv (10 rem)
- irradiation is caused by internally deposited radionuclides and is not uniform throughout the body
- the exposed population differs significantly from the atomic bomb survivor study group or
- some combination of these conditions exists.

For stochastic effects, the ICRP adopted the risk associated with 0.05 Sv (5 rem) in a year, delivered to every organ, as the basis for its dose-limitation system (ICRP 1977). Therefore, the stochastic annual limit on intake (ALI) for each radionuclide is the quantity that, if inhaled, would cause the same stochastic risk as a uniform, whole-body dose of 0.05 Sv (5 rem) delivered by external sources in 1 year. To establish these ALIs, the ICRP considered the possibility that a given radionuclide taken into the body eventually reaches the bloodstream and is then distributed selectively to the various organs and tissues, where DE is delivered over a time course determined by the retention capabilities of the organ or tissue and the physical characteristics of the radionuclide. Using a radiation risk coefficient specific for each organ or tissue and the 50-year integrated dose equivalent to the tissue, the risk associated with each is estimated. The total risk to the worker per quantity of this radionuclide inhaled is the sum of the individual organ or tissue risks. The intake that will produce the same overall stochastic risk as 0.05 Sv/yr (5 rem/yr) of uniform external radiation can then be readily calculated as the ALI. Of course, a worker may be exposed to several airborne radionuclides and to external radiation as well. In that case, the total risk is still limited to that associated with 0.05 Sv (5 rem) in a year from uniform external radiation. Compliance is achieved if the fraction of the external dose limit that is received, added to the fraction of ALI inhaled for each radionuclide, does not exceed unity.

The risk of hereditary effects is included in a special way that, in the view of the ICRP, renders it additive to the cancer fatality risk. The ICRP considered only detrimental effects that the worker is likely to experience personally, so that effects manifested after the second generation are not included in the genetic risk coefficient used. The coefficient is also limited to very serious genetic effects (i.e., those comparable in severity to premature death).

Although all organs and tissues receive the same DE under uniform exposure conditions, the cancer risks for a given dose in each organ are not the same. Each organ or tissue contributes to the overall risk based on the relative sensitivity of tissue to radiation-induced cancer. This fraction is called the weighting factor, and the sum of the weighting factors for all tissues is unity. The product of the weighting factor and the DE is the effective dose equivalent (EDE). This quantity is used for both external and internal irradiation and may be used for individual organs and tissues or for the sum of all organs and tissues. The unit used for either quantity is the same as for the DE, namely, the sievert (or rem). In the unique case of uniform irradiation of all organs and tissues, the sum of their EDEs is by definition equal to the whole-body DE. The EDE may be determined irrespective of the degree of uniformity among the organ or tissue doses. The sum of the EDEs is not allowed to exceed 0.05 Sv/yr (5 rem/yr).

The committed dose equivalent (CDE) is a quantity defined as the 50-year integrated DE to a specific organ or tissue following the inhalation of a radionuclide. This quantity is still used, but only in connection with nonstochastic effects. The committed effective dose equivalent (CEDE) is the same quantity as the CDE, with the exception that, in the case of the CEDE, each dose equivalent is multiplied by the tissue or organ weighting factor. The rem (or sievert) is also the unit for both of these quantities.

The mathematical weighting method used by the ICRP is shown in Table G-3. The first column lists the organs, and the second column lists the risk coefficients from ICRP Publication 26 (1977) and their sum, namely, 1.65×10^{-4}. This sum is the total annual risk to the exposed person, assuming exposure to these organs at 0.01 Gy/yr (1 rad/yr).[a] The fraction of this risk per rad for each organ can be obtained by dividing its risk coefficient by 1.65×10^{-4}. These fractions represent the relative sensitivity of the organs; they are the weighting factors and are designated by the symbol w_T, where T represents the organ or tissue. The weighting factors appear in column three of the table. If T is the dose equivalent to tissue T, then $w_T H_T$ is the

(a) Multiplication by 5 gives the annual risk at 0.05 Gy/yr (5 rad/yr) (i.e., 8.25×10^{-4}/yr). This risk value means that if groups of 10,000 workers were to receive the dose limit every year for their entire careers, data as of the mid-1970s indicate that an average of 8.25 fatal occupational radiation-induced cancers per year would occur within each group. Assuming the approximate worst case of 45 years of exposure, the toll theoretically would be about 370 deaths per group, or almost 4 percent.

weighted DE. For example, w_T for the lung is 0.12. If a weighted lung dose of H rem is set equal to a highly penetrating, uniform whole-body dose of 5 rem, then

$0.12\ H = 0.05$ Sv (5 rem) and
$H = 4.17$ Sv (41.7 rem).

By hypothesis and analogy, an annual DE of 0.417 Sv (41.7 rem) to only the lung would have the same effect as 0.05 Sv (5 rem) to all of the organs combined. For this reason, $w_T H_T$ is called the EDE.

Nonstochastic effects have thresholds, and they become more severe as the dose gets larger. The ICRP believes that none of the thresholds will be exceeded if the annual dose to any tissue or organ does not exceed 0.5 Gy (50 rad). This nonstochastic limit is reflected in Table G-3, where it is evident that nonstochastic effects are controlling for all but four organs that have the largest weighting factors, the most sensitive organs with respect to stochastic effects.

Table G-3. ICRP Publication 26 Risk Weighting System

Organs	Risk Coefficients, Effects per Organ-rem	Weighting Factors	Organ DE Causing Same Risk as 5 rem to Whole Body, rem	Annual DE Permitted, Exposure of One Organ, rem/yr
Gonads	4×10^{-5}	0.25	20	20
Breasts	2.5×10^{-5}	0.15	33-1/3	33-1/3
Lung	2×10^{-5}	0.12	41-2/3	41-2/3
Red marrow	2×10^{-5}	0.12	41-2/3	41-2/3
Bone	5×10^{-6}	0.03	166-2/3	50
Thyroid	5×10^{-6}	0.03	166-2/3	50
1st RO[(a)]	1×10^{-5}	0.06	83-1/3	50
2nd RO	1×10^{-5}	0.06	83-1/3	50
3rd RO	1×10^{-5}	0.06	83-1/3	50
4th RO	1×10^{-5}	0.06	83-1/3	50
5th RO	1×10^{-5}	0.06	83-1/3	50
Totals	1.65×10^{-4}	1.0		

(a) The remainder organs (ROs) are the five organs that receive, from a given radionuclide, the highest EDE, integrated over 50 years.
Note: To convert rem to sievert, multiply by 0.01.

G.1.1.4.2 Nonstochastic Effects

Nonstochastic effects refer to those, such as radiation-induced cataracts, for which the severity of the effect depends on radiation dose. They typically are not observed unless the radiation dose exceeds a minimum threshold, whereas the probability of stochastic effects is assumed to be greater than zero, although very small, even at very low doses. Therefore, radiological protection for nonstochastic effects is based on limiting exposures to levels that prevent the effect, rather than on controlling the probability of occurrence, as discussed previously for stochastic effects. For tissues such as the lens of the eye, the skin, and the extremities, radiation protection standards are intended primarily to control the dose from external sources. For internal organs, it is necessary to control the dose from internally deposited radionuclides as well. Because radiation can damage or kill cells if the dose is sufficiently high, a nonstochastic dose limit must be established for all tissues, including tissues other than those mentioned above.

ICRP Publication 41 (1983) provides the technical justification supporting the position that, with the exception of the lens of the eye, nonstochastic effects will not be observed among adults if the DE from external and internal radiation combined to every organ and tissue is less than 0.5 Sv/yr (50 rem/yr). The NRC is not aware of later radiobiological information indicating that this dose limit should be changed and notes that the ICRP retained this value in the 1990 revision of its recommendations (ICRP 1991).

G.1.1.4.3 Risk Coefficient Selection for This Supplement

The BEIR-V risk estimate can be arithmetically converted to the more familiar terminology of 8 cancer fatalities among 10,000 people exposed to 10 person-Sv (10,000 person-rem), leading to a convenient risk coefficient of 8×10^{-4} fatalities per person-rem. This coefficient is considered useful for estimating fatalities among large populations irradiated instantaneously and uniformly to individual external radiation doses of 0.1 Sv (10 rem) or more. However, since no dose or dose rate effectiveness factor (DDREF) is included in this risk factor, the fatality estimates become speculative as the individual doses and the size of the exposed population become progressively smaller. A DDREF of 2 has been recommended by the ICRP (1991) for doses below 0.2 Gy (20 rad) and dose rates below 0.1 Gy/h (10 rad/h), which corresponds to a risk coefficient 4.0×10^{-4} cancer fatalities per person-rem.

The risk coefficients for fatal cancer and hereditary effects (listed in Table G-4) are taken from ICRP (1991). The coefficients are consistent with the risk factors reported in BEIR-V if a DDREF of 2 is applied. The somewhat higher risk coefficients for the general population as compared to workers reflects the fact that individuals under age 18 at the time of exposure are more susceptible to radiation-induced cancer. A person must be 18 years or older to be

Table G-4. Nominal Probability Coefficients Used in this Supplement[(a)]

Health Effect	Occupational	Public
Fatal cancer	4	5
Hereditary	0.6	1

(a) Estimated number of excess effects among 10,000 people receiving 100 person-Sv (10,000 person-rem).

Source: ICRP Publication 60 (1991).

employed as a radiological worker. Excess hereditary effects are listed separately because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among people receiving instantaneous and near-uniform exposures of 0.1 Sv (10 rem) or more. As applied to low-level environmental and occupational exposures, risk factors for radiological health effects are subject to substantial uncertainty. The lower limit of the range for these risk coefficients is assumed to be zero because there may be biological mechanisms that can repair damage caused by radiation at low doses and/or dose rates.

G.1.2 Occupational Protection Standards

Occupational radiation protection standards have been in effect since 1947, and have generally been revised downward over the years, from 1.0 roentgen/wk (or about 50 roentgen/yr) in 1947 to the current 0.05 Sv/yr (5 rem/yr) total effective dose equivalent (TEDE). For an historical overview of development of these regulations, see NRC (1996), Appendix E. The current regulation implements the concept of TEDE, as developed by ICRP Publication 26 (1977). This methodology accounts for both exposure to radiation from external sources and intakes of radionuclides into the body in assessing compliance with the standards. Standards that were previously in effect applied only to external dose and did not account for dose from intakes of radionuclides by workers, which were assessed separately. In practice, radionuclide intakes account for a small fraction of the total dose received by workers at nuclear power facilities.

Historical dose data for nuclear power plant workers are presented in Section G.2. Table G-5 presents a summary of the occupational standards in the 1991 revision of 10 CFR Part 20. On an annual basis, the whole-body limit has decreased from 12 roentgen (3 roentgen per quarter) in 1957 (external radiation only) to 0.05-Sv (5-rem) TEDE (external plus internal).

Regulatory control over the intake of radioactive materials in the workplace has always been a complex issue. Beginning in 1991, the NRC adopted the method published by the ICRP in Publication 26 (ICRP 1977). Under the ICRP method, the dose to each significantly irradiated organ is weighted according to its radiation sensitivity. The weighted doses are summed to produce an EDE that can be added to the dose from external sources.

The revised 10 CFR Part 20 provides additional flexibility for establishing more accurate dose controls. It allows the use of actual particle-size distribution and physiochemical characteristics of airborne particulates to define site-specific derived air concentration limits. With NRC approval, these modified concentration limits can be used in lieu of generic values provided in 10 CFR Part 20. Such adjustments result in more precise estimates that use actual exposure conditions, as compared to generic assumptions.

The 1991 revision to 10 CFR Part 20 codifies a requirement that licensees implement a program to maintain radiation doses ALARA. Compliance with the commitments is required through the licensing process in 10 CFR Part 50 and the technical specifications. Two Regulatory Guides have been issued to provide guidance on ALARA programs for nuclear power plants: one on ALARA philosophy in NRC Regulatory Guide 8.10, Rev. 1R (NRC 1977), and one on implementation in NRC Regulatory Guide 8.8, Rev. 3 (NRC 1978). Nuclear power plant licensees are required to maintain and implement adequate plant procedures that contain ALARA criteria. During plant licensing, applicants commit to implement ALARA programs consistent with Regulatory Guides 8.8 and 8.10.

Table G-5. Occupational Dose Limits for Adults in 10 CFR Part 20[a]

Tissue	External Radiation	Internal Plus External Radiation
Whole Body	0.05 Sv/y (5 rem/yr) total DE,[b] not to exceed 0.5 Sv/y (50 rem/yr) total DE to any individual organ or tissue other than the lens of the eye	0.05 Sv/yr (5 rem/year) TEDE,[c] not to exceed 0.5 Sv/yr (50 rem/yr) total DE to any individual organ or tissue other than the lens of the eye
Lens	0.15 Sv/yr (15 rem/yr)	
Extremities, Including Skin	0.5 Sv/yr (50 rem/yr)	
All Other Skin	0.5 Sv/yr (50 rem/yr)	

(a) These revised 10 CFR Part 20 standards became effective on January 1, 1994.
(b) The total DE is the sum of the EDE (at 1 cm [0.39 in] depth) and the CDE from nuclides deposited in the body.
(c) The TEDE is the sum of the EDE (at 1 cm depth [0.39 in]) and the CEDE from nuclides deposited in the body.

G.1.3 Public Radiation Protection Standards

For many years, the ICRP and NCRP recommended dose limits for the public that were 10 percent of those for workers. During the 1980s, both organizations adopted a more conservative value of 2 percent. In 1985, the ICRP released a statement that its principal limit for the whole body was 0.001 Sv/yr (0.1 rem/yr) EDE (ICRP 1985). However, a subsidiary limit of 0.005 Sv/yr (0.5 rem/yr) is authorized, provided that the average dose over a lifetime does not exceed 0.001 Sv/yr (0.1 rem/yr). The ICRP limit for the skin and lens of the eye is 0.05 Sv/yr (5 rem/yr). In 1987, the NCRP recommended limits of 0.001 Sv/yr (0.1 rem/yr) EDE for the whole body under conditions of continuous or frequent exposure and 0.005 Sv/yr (0.5/yr) for infrequent exposure (NCRP 1987). The NCRP limit for the lens of the eye, skin, and extremities is 0.05 Sv/yr (5 rem/yr).

The 1991 revision of 10 CFR Part 20 implements guidelines consistent with the recommended limit of 0.001 Sv/yr (0.1 rem/yr) EDE (see Table G-6). Provision is made for temporary increases to 0.005 Sv/yr (0.5 rem/yr) with prior authorization and justification. Hourly and annual dose rate limits for unrestricted areas are also included.

Licensees may also demonstrate compliance with the provisions of 10 CFR Part 20 by showing that annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of an unrestricted area do not exceed the values specified in 10 CFR Part 20, Appendix B, Table 2.

Table G-6. Dose Limits for an Individual Member of the Public under 10 CFR Part 20[a]

Applicability by Pathway	Dose Limits
Annual dose, all pathways[b]	1 mSv/yr (0.1 rem/yr) TEDE[c]
External dose rate, unrestricted areas	0.02 mSv/h (0.002 rem/h) or 0.5 mSv/yr (0.05 rem/yr)
Temporary Annual Dose, all pathways[d]	5 mSv/yr (0.5 rem/yr) TEDE[c]
ALARA dose constraint, air emissions[e]	0.1 mSv/yr (0.01 rem/yr) TEDE[c]

(a) These revised 10 CFR Part 20 standards became effective on January 1, 1994.
(b) Excludes contribution from materials disposed to sanitary sewers.
(c) The TEDE is the sum of the EDE (at 1 cm depth) and the CEDE from nuclides deposited in the body.
(d) Temporary increases in the public dose limit are subject to prior authorization from the NRC and other constraints to ensure the increase is justified and controlled to be ALARA.
(e) This is not a 10 CFR Part 20 dose limit, but is given to ensure consistency with air emissions standards for Federal facilities in 40 CFR Part 61.

The NRC has not established standards for radiological exposures to biota other than humans on the basis that limits established for the maximally exposed members of the public would provide adequate protection for other species. In contrast to the regulatory approach applied to human exposures, the fate of individual nonhuman organisms is of less concern than the maintenance of the endemic population (NCRP 1991). Experience has shown that population stability is crucial to survival of most species. However, in many ecosystems individual members of a species may suffer relatively high mortality rates from natural causes without creating detrimental effects to the population as a whole. The exception might be for threatened or endangered species where protection of the individual may be required in order to avoid detrimental effects on a relatively small population.

Evaluations of radiation exposures to nonhuman biota at nuclear power facilities have not identified exposures that could be considered significant in terms of harm to the species, or which approach the public exposure limits in 10 CFR Part 20. Limiting exposure in humans to 1 mSv/yr (100 mrem/yr) will lead to dose rates to plants in animals in the same area of less than 1 mGy per day (100 mrad per day). The International Atomic Energy Agency (IAEA) concludes that there is no convincing evidence from scientific literature that chronic radiation dose rates below 1 mGy per day (100 mrad per day) will harm plant or animal populations (IAEA 1992). Because of the relatively lower sensitivity of nonhuman species to radiation, and the lack of evidence that nonhuman populations or ecosystems would experience detrimental effects at radiation levels found in the environment around nuclear power stations, effects on these biota are not evaluated in detail for the purposes of this Supplement.

In addition to the basic standards mentioned above, 10 CFR 50.36(a) contains license conditions that are imposed on licensees in the form of technical specifications applicable to effluents from nuclear power reactors. These specifications ensure that releases of radioactive materials to unrestricted areas during normal operations, including expected operational occurrences, remain ALARA. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for operation for light-water reactors (LWRs) to meet the ALARA requirements. As a part of the licensing process, all licensees have provided reasonable assurance that the design objectives will be met for all unrestricted areas even during the decommissioning process. Title 10 CFR Part 20 requires compliance with the U.S. Environmental Protection Agency regulation 40 CFR Part 190, which also contains ALARA limits. The dose constraints are summarized in Tables G-7 and G-8.

Specific radiological criteria for license termination were added to 10 CFR Part 20 in 1997, and the basis for public health and safety considerations is discussed in NUREG-1496 (NRC 1997). These criteria limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) from all

Table G-7. 10 CFR Part 50, Appendix I, Design Objectives and Annual Limits on Radiation Doses to the General Public from Nuclear Power Facilities[a]

Tissue	Gaseous	Liquid
Total body	0.05 mSv (5 mrem)	0.03 mSv (3 mrem)
Any organ, all pathways	--	0.01 mSv (10 mrem)
Ground-level air dose	0.1 mGy (10 mrad) gamma and 0.3 mGy (30 mrad) beta	--
Any organ,[b] all pathways	0.15 mSv (15 mrem)	--
Skin	0.15 mSv (15 mrem)	

(a) Calculated doses.
(b) Particulates, radioiodines.

Table G-8. 40 CFR 190, Subpart B, Annual Limits on Doses to the General Public from Nuclear Power Operations[a]

Tissue	Limit	Source
Total body	0.25 mSv (25 mrem)	All effluents and direct radiation from nuclear power operations
Thyroid	0.75 mSv (75 mrem)	"
Any other organ	0.25 mSv (25 mrem)	"

(a) Calculated doses.

pathways following unrestricted release of a property. In cases where unrestricted release is not feasible, the licensee must provide for institutional controls that would limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) during the control period and to 1 mSv/yr (100 mrem/yr) after the end of institutional controls. These criteria will largely determine the types and extent of activities undertaken during the decommissioning process to reduce the radionuclide inventory remaining onsite.

G.2 Nuclear Power Plant Exposure Data

G.2.1 Occupational Dose Experience

Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20. The exposure pathway of primary interest is from sources that are external to the body. Measurements of the whole-body dose are normally derived from personal dosimeters worn by each worker, and they represent a relatively uniform dose to all organs of the body. Since 1984, many of the nuclear power plants have provided dosimetry programs accredited by the National Bureau of Standards (NBS, now National Institute of Standards and Technology [NIST]). In 1988, NBS/NIST accreditation became an NRC requirement.

Whole-body dose data from NRC-licensed LWRs are shown in Table G-9 for the years 1973 through 1999 (NRC 2000). For each year, the number of reactors, the number of workers receiving measurable exposures, the average annual dose per worker, the collective dose for all reactors combined, and the number of individuals exceeding 0.05 Sv (5 rem) are listed. Until 1991, the limit for exposure to workers was 0.03 Sv per quarter (3 rem per quarter), or a maximum of 0.12 Sv/yr (12 rem/yr), with an average of 0.05 Sv/yr (5 rem/yr). The collective dose is the sum of doses to workers at all plants. The collective doses to nuclear plant workers decreased from a peak of over 55 person-Sv/yr) (55,000 person-rem/yr) in 1983-1984 to less than 15 person-Sv/yr (15,000 person-rem/yr) in 1998-1999, although there are currently about 25 percent more operating plants than in the mid-1980s. Average annual doses to workers have likewise decreased from just under 0.01 Sv/yr (1 rem/yr) in the early 1970s to less than 0.25 mSv/yr (0.25 rem/yr) after 1997. Whole-body doses exceeding 0.05 Sv/yr (5 rem/yr) have been infrequent since 1985, and no doses at that level have been reported since 1989. Nuclear power plant workers may also be exposed to airborne radioactive material, primarily fission and corrosion products, but such exposures have historically been small in comparison with external doses. A study of intake data indicated that for cobalt-58 and cobalt-60, the most prevalent radionuclides, very few of the workers had organ burdens of more than 1 percent of the maximum permissible (see Baker 1996).

These data indicate that occupational exposures within the nuclear power industry have been significantly reduced since 1973. Individual doses are characteristically far below the regulatory limit, and the annual average is less than 5 percent of the 5 rem per year limit that is now in effect. Effective implementation of the ALARA concept is largely responsible. The range of risks associated with these exposures are discussed in Section G.1.

Occupational doses at reactors that are undergoing decommissioning are typically lower than those accumulated at operating facilities, as indicated in the Table G-9 data for reactors that are no longer operating. Between 1995 and 1999, the collective dose from shutdown facilities typically amounted to a few hundred person-rem per year, and the annual average dose per worker was comparable to, or lower than, that for operating facilities. A comparison in Table G-10 of the occupational doses at 12 facilities before and after they were shutdown confirms that decommissioning would not be expected to increase occupational doses on average, although some phases of the process may result in temporarily higher collective doses depending on the activities in progress and the number of workers involved.

Table G-9. Occupational Dose at Light Water Reactors (LWRs) - Comparison of Operating Reactors to Reactors No Longer in Operation[a]

Year	Number of Workers with Measurable Exposure[b]	Collective Dose, person-rem[c]	Average Dose per Worker with Measurable Exposure, rem[c]	Total Number with Dose > 5 rem[d]	Number of Reactors	Average Collective Dose per Reactor-Year, person-rem[e]
			Operating Reactors			
1973	14,780	13,962	0.945	--	24	582
1974	18,139	13,650	0.753	--	33	414
1975	28,234	20,901	0.740	--	44	475
1976	34,515	26,105	0.756	--	52	502
1977	38,985	32,521	0.834	351	57	571
1978	42,777	31,785	0.743	159	64	497
1979	60,299	39,908	0.662	180	67	596
1980	74,629	53,739	0.720	391	68	790
1981	76,772	54,163	0.706	210	70	774
1982	79,309	52,201	0.658	135	74	705
1983	79,709	56,484	0.709	169	75	753
1984	90,520	55,251	0.610	74	78	708
1985	86,926	43,048	0.495	1	82	525
1986	93,979	42,386	0.451	0	90	471
1987	96,231	40,406	0.420	0	96	421
1988	96,013	40,772	0.425	1	102	400
1989	100,084	35,931	0.359	0	107	336
1990	98,567	36,602	0.371	0	110	333
1991	91,086	28,519	0.313	0	111	257
1992	94,172	29,297	0.311	0	110	266
1993	86,193	26,364	0.306	0	108	244
1994	71,613	21,704	0.303	0	109	199
1995	70,821	21,688	0.306	0	109	199
1996	68,305	18,883	0.276	0	109	173
1997	68,372	17,149	0.251	0	109	157
1998	57,466	13,187	0.229	0	105	126
1999	59,216	13,666	0.231	0	104	131
Average 1973-1999	69,545	32,603	0.514	73		430
Average 1995-1999	64,836	16,915	0.259	0		157
			Permanently Shutdown Reactors[f]			
1995	699	262	0.375	0	6	44
1996	974	165	0.169	0	8	21
1997	1144	136	0.119	0	7	19
1998	2178	430	0.197	0	11	39
1999	2856	430	0.151	0	13	33
Average 1995-1999	1,570	285	0.202			31

(a) Data Source: NUREG-0713, Vol. 21 (NRC 2000)
(b) 1973-1976 data are not adjusted for multiple reporting of transient individuals
(c) To convert rem to sievert, multiply by 0.01.
(d) Number of workers by dose range not available for 1973-1976 The dose limit was 3 rem/quarter (12 rem/yr) before the 1991 revision of 10 CFR Part 20; thereafter, it was reduced to 5 rem/yr.
(e) To convert person-rem to person-sievert, multiply by 0 01.
(f) Includes plants not in operation for a full year as of December 31 of the reporting year.

Table G-10. Occupational Whole-Body Dose at Decommissioning Reactors, Comparison of Dose During Operations to Dose During Decommissioning

						Average Annual Occupational Dose, person-rem/yr			Maximum Annual Occupational Dose, person-rem/yr		
Nuclear Plant	Reactor Type	Capacity, MWe	Years in Operation	Years Post Shutdown	D&D Method	Normal Power Operations	Post Shutdown	Post Shutdown as % of Operations	Operations	Post Shutdown	Post Shutdown as % of Operations
Ft. St. Vrain	HTGR[a]	330	10	12	DECON	3	106	4076.9	6	210	3500
Big Rock Point	BWR[b]	67	34	2	DECON	166	116	69.7	277	144	52.0
La Crosse	BWR	48	17	13	SAFSTOR	247	19	7.8	313	105	33.5
Humboldt Bay, Unit 3	BWR	63	13	25	SAFSTOR	294	183	62.4	339	1905	561.9
Yankee Rowe	PWR[c]	175	30	8	DECON	159	75	47	246	156	63.4
Haddam Neck	PWR	560	28	3	DECON	355	137	38.5	590	261	44.2
Maine Yankee	PWR	860	25	3	DECON	326	154	47.1	653	173	26.5
Trojan	PWR	1080	17	7	DECON	346	38	11	567	52	9.2
San Onofre, Unit 1	PWR	436	25	8	SAFSTOR	512	16	3.1	880	16	1.8
Rancho Seco	PWR	873	14	10	SAFSTOR	385	9	2.3	787	41	5.2
Zion, Units 1 and 2	PWRs	2080	24	2	DECON	645	8	1.2	1043	12	1.2
Average All LWR						343	75	29	570	287	79.9
Average BWR						235	106	46.6	310	718	215.8
Average PWR						390	62	21.5	681	102	21.6
Average DECON						333	88	35.8	563	133	32.7
Average SAFSTOR						359	57	18.9	580	517	150.6

(a) High-temperature gas-cooled reactor.
(b) Boiling water reactor.
(c) Pressurized water reactor.

Table G-11. Occupational Dose by Activity During Decommissioning

Nuclear Plant	Reactor Type	Capacity, MWe	D&D Method	Cumulative Dose Post Shutdown, person-rem[a]	Percent of Total Cumulative Dose to Completion by Activity: Large Component Removal, %	Systems, Structures, and Components Removal, %	Other Decon Activities, %	SNF Management, %	Transportation, %	SAFSTOR Activities, %
Fort St. Vrain	HTGR[b]	330	DECON	433	45.1	25.6	13.8		15.5	
Big Rock Point	BWR[c]	67	DECON	700						
Haddam Neck	PWR[d]	560	DECON	996	37	28.7	19.3	8.7	6.1	
Maine Yankee	PWR	860	DECON	946	9.9	12.8	74.2	3		
Trojan	PWR	1080	DECON	556	22.7	50.7	5.4	21.2		
Zion, Units 1 and 2	PWRs	2080	SAFSTOR	637						
Humboldt Bay, Unit 3	BWR	63	SAFSTOR	354			50.8		3.7	45.5
Rancho Seco	PWR	873	SAFSTOR	483	39.1	47.6	5.8			7.5
San Onofre, Unit 1	PWR	436	SAFSTOR	1100						
Average All Plants				689	26.9	28	36.9	8.3	8.4	18.1
Number of Plants				9	6	6	7	4	3	3
Occupational Dose in Decommissioning BWRs										
Average BWR				527			50.8		3.7	45.5
Number of Plants				2			1		1	1
BWR SAFSTOR				354			50.8		3.7	45.5
BWR DECON				700						
Occupational Dose in Decommissioning PWRs										
Average PWR				786	23.2	28.4	38.7	8.3	6.1	4.4
Number of Plants				6	5	5	5	4	1	2
PWR SAFSTOR				792	23.3	25	47.2	0.3		4.4
PWR DECON				784	23.2	30.8	33	11	6.1	

(a) Dose is estimated for activities during decommissioning at plants that have not reached license termination.
(b) High-temperature gas-cooled reactor.
(c) Boiling water reactor.
(d) Pressurized water reactor.

Table G-12. Reactor Vessel Removal Information and Data

Nuclear Plant	Total Bequerels (Curies) Removed	Personnel Exposure person-sievert (person-rem)	Segmented components/ Lineal inches cut	Cutting Methods	Considerations for Planning and Implementation
Haddam Neck (in progress)	2.8×10^{16} (750,000)	1.77 (177)	• Core baffle • Core former plates • Core barrel in active fuel region • Lower core support plate • Lineal inches cut - 23,251	• Abrasive water • MDM cutting	• Worker exposure • Airborne contamination • Waste form and disposal costs • Cavity cleanup requirements • Schedule
San Onofre, Unit 1 (in progress)	$1\ 2 \times 10^{16}$ (330,000)	0.73 (73)	• Core region of the core barrel • Core baffles/formers • Lower core support plates • Lineal inches cut - 10,821	• Abrasive water • MDM cutting	
Maine Yankee (in progress)	Not available	(actual to date) 0 24 (24)	• Upper guide structure • Upper core barrel • Core support barrel • Mid-core region • Thermal shield • Lineal inches cut - 14,000	• Abrasive water jet (AWJ) • Conventional machining	• Avoid thermal processing • Use AWJ and conventional machining vs. plasma arc and MDM/EDM to reduce the occupational dose • Modeled all the cuts in a 3D CAD system before actually performing any of the dismantlement • Segregating, capturing, and confining AWJ cutting waste • Solid waste collection system • Cavity water treatment system • Much Maine Yankee dismantlement done under water and remotely, which cut down the worker dose • Abrasive Feed Assist System (patent pending) • Underwater AWJ Vision Enhancement - remote operability (patent pending) • Minimized amount of secondary waste • For underwater equipment, a maintenance and reliability issue • Sequence of cuts (low to high activity) reduced occupational exposure
Big Rock Point (in progress)	Not available	Not available	N/A	N/A	

Table G-12. (contd)

Nuclear Plant	Total Bequerels (Curies) Removed	Personnel Exposure (person-rem)	Segmented components/ Lineal inches cut	Cutting Methods	Considerations for Planning and Implementation
Trojan (completed)	74,000 (2,000,000)[a]	0.72 (72)	N/A	N/A	• Used the fuel transfer crane to lift the reactor vessel and place in the container • Removed reactor vessel with internals intact • The internals were grouted in place with low-density cellular concrete • Placed the reactor vessel on a heavy haul trailer for road transport to the rail • Shipped the reactor vessel with internals to U.S. Ecology, Richland, WA • Eliminated 74,000 Bq (2 million curies) from the Trojan nuclear facility site

(a) The Trojan plant reactor vessel was removed and shipped intact to the disposal facility; reactor vessel internals were not removed as in the other plants listed in this table.

Tables G-11 and G-12 list available data regarding the distribution of the cumulative collective worker dose among the major types of activities that would occur during a typical decommissioning process. The lack of resolution in much of the data and the small number of facilities involved (10) precludes a detailed analysis. However, it appears that the largest share of occupational doses might be expected for three general classes of activities: (1) large component removal (reactor vessel, steam generators), (2) removal of other plant systems, structures, and components, and (3) the remaining general decontamination activities. Data for removal of the reactor vessel (Table G-12) indicate that the choice of removal method (i.e., intact or segmented) may influence the collective dose associated with the operation. Data for plants electing the SAFSTOR alternative were not substantially different from plants undergoing more immediate DECON. The one exception was at Humboldt Bay, where the plant was maintained in a shutdown condition over an extended period of time. In that case, SAFSTOR activities accounted for a relatively large fraction of the total estimated occupational dose. In all cases, the estimated cumulative doses through the end of decommissioning for these plants were within the estimates presented in the 1988 GEIS (NRC 1988).

G.2.2 Dose to Members of the Public

Doses to members of the public from power reactor effluents were summarized in a series of NRC reports entitled *Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites*. The last volume published covers reactor operations during 1992 (NUREG/CR-2850, Baker 1996). Radioactive material is released in gaseous (airborne, and may contain particulates, such as radioiodine) and liquid (aqueous) effluents under stringently controlled conditions in accordance with technical specifications and NRC regulations. The term "dose commitment" indicates that the reported doses come from the inhalation and ingestion of radionuclides, as well as from external radiation from noble gases. The population dose caused by direct radiation from plant facilities is negligible. Table G-13 presents results obtained for the 18-year period ending in 1992. The public doses represent collective person-rem received by those who live within an 80-km (50-mi) radius of a site; data for individual sites also appear in this report. The population dose within 80 km (50 mi) of each plant is calculated for each operating reactor in the United States. The total collective dose is then obtained by combining the doses received by these populations. As with the occupational doses, collective dose to the public from reactor effluents has been decreasing steadily since the mid-1980s. The collective dose to members of the public is smaller by several orders of magnitude than the dose to plant workers.

Data on maximally exposed individuals from gaseous effluents is also reported annually to the NRC by each nuclear utility. Data for the period 1985-1987 were compiled in NUMARC (1989) and summarized in NRC (1996). A summary of the data is presented in Table G-14.

Inspection of this table reveals that the maximum doses to individuals via gaseous effluents are on the order of a few mrem per year, and the dose to an individual is orders of magnitude lower for most plants.

Table G-13. Summary of Collective Public and Occupational Doses for All Operating Nuclear Power Facilities Combined[(a)]

		Collective Public Dose, person-rem			
Year	**Number of Operating Reactors**[(b)]	**Liquid Effluents**	**Gaseous Effluents**	**Total**	**Average per reactor-yr, person-rem**
1975	44	76	1300	1300	30
1976	52	82	390	470	9.0
1977	57	160	540	700	12
1978	64	110	530	640	10
1979	67	220	1600	1800	27
1980	68	120	57	180	2.6
1981	70	87	63	150	2.1
1982	74	50	87	140	1.9
1983	75	95	76	170	2.3
1984	78	160	120	280	3.6
1985	82	91	110	200	2.4
1986	90	71	44	110	1.2
1987	96	56	22	78	0.81
1988	102	65	9.6	75	0.74
1989	107	68	16	84	0.79
1990	110	63	15	78	0.71
1991	111	70	17	88	0.79
1992	110	32	15	47	0.43

(a) Collective public dose calculated for those living within an 80-km (50-mi) radius of a nuclear plant site.

(b) Includes plants in operation at least 1 full year at the end of the reporting year.

Source: NUREG/CR-2850 (Baker 1996).

Note: To convert person-rem to person-sievert, multiply by 0.01.

Table G-14. Estimated Doses to the Maximally Exposed Individual from Routine Gaseous Effluents from Operating Facilities, mrem[a]

	1985	1986	1987
Average	2.8E-01	2.6E-01	9.1E-02
Minimum	7.8E-04	4.9E-04	1.0E-06
Maximum	1.8E+00	4.3E+00	8.9E-01
Number of plants reporting	26	33	34

(a) Data compiled from reports submitted to the NRC by each nuclear utility.
Adapted from NUMARC (1989).
Note: To convert millirem to millisievert, multiply by 0.01.

A comparison of more recent effluent release rates from both operating and decommissioning facilities (Table G-15) indicates that the gaseous release rates for many types of effluents are similar. Decommissioning facilities reported no emissions of radioiodine in their gaseous effluents, which would be as expected after the plants are shut down and defueled. Most of the iodine isotopes are short-lived and are not present in plants that have been out of operation for any length of time. Releases of longer-lived fission gases and particulate materials in gaseous effluents continue after the end of operation because of the need to maintain plant ventilation systems during activities associated with the decommissioning process. Radionuclide emissions in liquid effluents were typically lower in the shutdown facilities because the reactor core cooling systems were not operating, and the levels of radionuclides in circulating water systems needed to maintain the spent fuel pool are lower than in primary coolant for an operating plant.

Recent DEs to members of the public from emissions at operating and decommissioning facilities were similar, and the doses from gaseous effluents were within the ranges published in NRC (1996) for operating facilities. Both individual and collective doses were very low for liquid and gaseous effluents. Although information was available for a relatively small sample of facilities, there does not appear to be any reason to project substantial increases in emissions or public doses from reactors undergoing decommissioning compared to the levels experienced during normal operation of those facilities.

Table G-15. Summary of Effluent Releases Comparison of Operating Facilities and Decommissioning Facilities

Operating Reactors						
Reactor Type	**PWR**			**BWR**		
	Average	**Max**	**Min**	**Average**	**Max**	**Min**
Capacity (MWe)	829	912	760	972	1154	786
Gaseous Effluents - Total (Ci)	5.8E+01	1.5E+02	4.0E-01	9.3E+01	1.7E+02	1.2E+01
Fission and Activation Gases (Ci)	4.4E+01	1.4E+02	7.5E-02	8.3E+01	1.6E+02	1.5E+00
Iodines (Ci)	6.4E-07	1.3E-06	0	2.3E-03	5.1E-03	0
Particulates (Ci)	1.9E-05	3.8E-05	3.3E-07	8.9E-04	1.6E-03	3 0E-04
Gross Alpha (Ci)	--	--	--	--	--	--
Tritium (Ci)	1.4E+01	3.7E+01	3.2E-01	1.0E+01	1.2E+01	6.2E+00
Liquid Effluents - Total (Ci)	5.2E+02	6.7E+02	4.2E+02	1.2E+01	1.9E+01	6.9E+00
Fission and Activation Products (Ci)	1.6E-01	3.7E-01	8.5E-02	6.2E-02	9.4E-02	1.2E-02
Tritium (Ci)	5.2E+02	6.7E+02	4.2E+02	1.2E+01	1.9E+01	6.9E+00
Dissolved and Entrained Gases (Ci)	1.0E-01	3.8E-01	2.2E-04	4.3E-03	6.7E-03	1.8E-03
Gross Alpha (Ci)	1.2E-03	1.9E-03	4 4E-04	2.4E-06	3 8E-06	0

Decommissioning Reactors						
Reactor Type	**PWR**			**BWR**		
	Average	**Max**	**Min**	**Average**	**Max**	**Min**
Capacity, MWe	970	1080	860	65	67	63
Gaseous Effluents - Total (Ci)	2.1E+01	4.0E+01	2.6E+00	1.1E+02	2.1E+02	1.2E+00
Fission and Activation Gases (Ci)[a]	1.6E+01	1.6E+01	1.6E+01	2.1E+02	2.1E+02	2.1E+02
Iodines (Ci)	--	--	--	--	--	--
Particulates (Ci)	0	0	0	1.0E-04	2.0E-04	0
Gross Alpha (Ci)	--	--	--	0	0	0
Tritium (Ci)	1.3E+01	2.4E+01	2.6E+00	1.2E+00	1.2E+00	1.2E+00
Liquid Effluents - Total (Ci)	7.8E-01	1.4E+00	1.2E-01	3.3E-01	1.3E+00	1.0E-03
Fission and Activation Products (Ci)	3.5E-02	6.7E-02	2.6E-03	3.3E-01	1.3E+00	2.0E-04
Tritium (Ci)	7.4E-01	1.4E+00	1.2E-01	9.5E-04	1.1E-03	8.0E-04
Dissolved and Entrained Gases (Ci)	--	--	--	--	--	--
Gross Alpha (Ci)	0	3.0E-05	0	0	0	0

(a) The average, maximum, and minimum values for this radionuclide category are identical within each reactor type because only one facility of each type reported detectable emissions. Other facilities either did not report emissions for this category or indicated that emissions were below detection limits and, therefore, were not included in the calculation.

G.3 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

40 CFR 61. Code of Federal Regulations, Title 40, Protection of Environment, Part 61, "National emissions standards for hazardous air pollutants; regulations of radionuclides."

40 CFR 190. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 190, "Environmental radiation protection standards for nuclear power operations."

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G.4 Related Documents

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Appendix H

Summary of Environmental Impacts from Decommissioning Activities

Appendix H

Summary of Environmental Impacts from Decommissioning Activities

This appendix provides two tables that summarize findings from the analysis of the environmental impacts from decommissioning of permanently shutdown nuclear reactors. Table H-1 shows those issues and decommissioning activities that have no environmental impacts. Licensees may conduct these activities without further consideration of the potential environmental impacts. Table H-2 presents each environmental issue that was evaluated, provides the activities that were determined potentially to have environmental impacts, and then states whether the impacts related to the issue's associated activities were determined to be generic or site-specific for all variables. The significance level is identified and a short discussion of the finding is provided on the right-hand side of the table. Section 4.1 defines the significance levels and explains the distinction between generic or site-specific issues.

Table H-1. Issues and Activities with No Environmental Impacts

Issue	Activity
Onsite/Offsite Land Use	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlment phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Entombment Transportation License termination activities
Water Use	Remove fuel • Drain primary system • Process liquid Organizational changes • Adjust site training • Changes to licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal • Steam generator and other large components intact or cut up Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontaminate piping inside walls • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs

Table H-1. (contd)

Issue	Activity
Water Use (contd)	System dismantlement Entombment • Install engineered barriers • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment LLW packaging and storage Transportation License termination activities
Water Quality	Organizational changes Stabilization • Isolate SSCs that are no longer required • Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large Component Removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement • Removal of structures Entombment LLW packaging and storage Transportation License termination activities

Table H-1. (contd)

Issue	Activity
Air Quality	Remove fuel Organizational changes • Reduce staff • Adjust site training • Change licensing basis - site-specific Stabilization Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR • De-energize systems, put in monitors where they are needed • Perform a radiological assessment Storage (SAFSTOR) • Monitor systems and radiation levels etc. • Do preventive and corrective maintenance on SSCs • Maintain the security system Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system System dismantlement Entombment • Disconnect operational systems (e.g., electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment LLW packaging and storage License termination activities

Table H-1. (contd)

Issue	Activity
Aquatic Ecology	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large Component Removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement • Rubblization Entombment LLW packaging and storage Transportation License termination activities
Terrestrial Ecology	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs

Table H-1. (contd)

Issue	Activity
Terrestrial Ecology (contd)	System dismantlement Structure dismantlement • Rubblization Entombment LLW packaging and storage Transportation License termination activities
Threatened and Endangered Species	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement • Rubbliztion Entombment LLW packaging and storage Transportation License termination activities
Radiological	Organizational changes • Changes to licensing basis - site-specific Create nuclear island • Reduce the security area to that around the fuel • Change security function • Install or modify chemistry controls

Table H-1. (contd)

Issue	Activity
Radiological (contd)	Storage (SAFSTOR) • Maintain the security system • Maintain effluent and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain the security system • Maintain effluent and environmental monitoring programs Entombment • Entomb facility in concrete Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste
Radiological Accidents	Organizational changes • Reduce staff • Employ contractor or other additional staff Stabilization • Isolate SSCs that are no longer required • Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs Structure dismantlement • Rubblization Entombment • Install engineered barriers • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment

Table H-1. (contd)

Issue	Activity
Radiological Accidents (contd)	• Place material inside containment • Entomb facility in concrete Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities
Occupational Issues	Organizational changes • Reduce staff • Employ contractor or other additional staff • Changes to licensing basis Post-shutdown surveys Create nuclear island • Reduce the security area to that around the fuel • Change security function Storage preparation activities for SAFSTOR • Perform a radiological assessment Storage (SAFSTOR) • Monitor system and radiation levels • Maintain security system • Maintain efficient and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain the security system • Maintain effluent and environmental monitoring programs Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities • Partial site release

Table H-1. (contd)

Issue	Activity
Cost	Remove fuel • Transfer fuel to spent fuel pool Create nuclear island • Install or modify chemistry controls
Socioeconomic	Remove fuel Organizational changes • Adjust site training • Change licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation License termination activities
Environmental Justice	Remove fuel Organizational changes • Adjust site training • Change licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR)

Table H-1. (contd)

Issue	Activity
Environmental Justice (contd)	Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging storage Transportation • Move equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities
Cultural Impacts	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High pressure water spray of surface • Do preventative and corrective maintenance on SSCs • Maintain security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities

Table H-1. (contd)

Issue	Activity
Aesthetic Issues	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Entombment • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment • Lower ceiling (optional) LLW packaging and storage Transportation License termination activities
Noise	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement

Table H-1. (contd)

Issue	Activity
Noise (contd)	Entombment • Disconnect operational systems (e.g. electrical and fire protection) • Place material inside containment • Lower ceiling (optional) LLW packaging and storage Transportation License termination activities
Irretrievable Resources	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 Entombment Transportation • Equipment into site License termination activities

Table H-2. Summary of Environmental Impacts

Onsite/Offsite Land Use (4.3.1)
Activities that Could Impact Onsite/Offsite Land Uses
Large Component Removal Structure dismantlement (Laydown yards) LLW packaging and storage
Generic
Yes - For onsite activities for all reactor types No - For offsite activities for all reactor types
Impact and Summary of Findings
• Onsite land use activities - SMALL • Offsite land use activities - site specific

Table H-2. (contd)

Water Use (4.3.2)
Activities that Could Impact Water Use
Remove Fuel • Transfer fuel to spent fuel pool Organizational changes (affects potable water use) • Reduce staff • Employ contractor staff or other additional staff Large Component Removal • Remove reactor vessel and internals Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • High-pressure water spray Structure dismantlement (dust control) Entombment • Lower containment ceiling (dust control) • Entomb facility in concrete
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to water use that are identified in this Supplement - SMALL The amount of water used during decommissioning is much less than the amount of water used during operations except for possible short periods of time when potable water use may temporarily increase with staffing levels.

Table H-2. (contd)

Water Quality (4.3.3)
Activities that Could Impact Water Quality
Remove Fuel Stabilization • Drain and flush system Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • High-pressure water spray Structure dismantlement (pH concerns) • Rubblization
Generic
Yes - For surface water and groundwater for all reactor types
Impact and Summary of Findings
All activities related to water quality (surface and groundwater) that are identified in this Supplement except for onsite disposal of demolition debris - SMALL The releases during decommissioning are within the NPDES guidelines.

Table H-2. (contd)

Air Quality (4.3.4)
Activities that Could Impact Air Quality
Organizational changes (additional worker vehicle traffic) • Employ contractor staff or other additional staff Stabilization • Drain and flush system • Isolate system structures and components Preparation for Storage (SAFSTOR) • Reactor coolant system ventilation pathways • Containment ventilation pathways Storage (SAFSTOR) • Maintain effluent and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain effluent and environmental monitoring programs Structural dismantlement (dust control) Entombment • Install engineered barriers (dust control) • Lower containment ceiling (dust control) • Entomb facility in concrete (vehicle traffic) Transportation
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to air quality that are identified in this Supplement - SMALL Any fugitive dust from decommissioning activities are temporary and can be controlled by mitigative measures. Air quality impacts from workers' vehicles and for movement of materials to and from the site are expected to be negligible.

Table H-2. (contd)

Aquatic Ecology (4.3.5)
Activities that Could Impact Aquatic Ecology
Structure dismantlement • Remove structures that were necessary for plant operation (intake structure)
Generic
Yes - For activities within the operational area and reactor types No - Requires site-specific analysis if the activities are outside the boundaries of the operational area.
Impact and Summary of Findings
Activities within the boundaries of the operational areas - SMALL Activities outside the boundaries of the operational areas - site-specific

Table H-2. (contd)

Terrestrial Ecology (4.3.6)
Activities that Could Impact Terrestrial Ecology
Stabilization • Rewiring of site to eliminate unneeded electrical circuits (includes repowering from the outside) Large Component Removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas Structure dismantlement • Remove structures that were necessary for plant operation
Generic
Yes - For activities within the operational area and for all reactor types No - Requires a site-specific analysis if the activities are outside the boundaries of the operational areas.
Impact and Summary of Findings
Activities within the boundaries of the operational areas - SMALL Activities outside the boundaries of the operational areas - site-specific

Table H-2. (contd)

Threatened and Endangered Species (4.3.7)
Activities that Could Impact Threatened and Endangered Species
Stabilization • Rewiring of site to eliminate unneeded electrical circuits (includes repowering from the outside) Large component removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil Structure dismantlement • Remove structures that were necessary for plant operation
Generic
No - Requires a site-specific analysis and continued monitoring of site activities concerning the presence of threatened and endangered species.
Impact and Summary of Findings
A site-specific analysis is required. The appropriate Federal agency (either U.S. Fish and Wildlife Service or the National Marine Fisheries Service) must be consulted about the presence of threatened or endangered species.

Table H-2. (contd)

Radiological (4.3.8)
Activities that Could Have Radiological Impacts
Remove Fuel Organizational changes • Reduce staff • Employ contractor or additional staff • Adjust site training Stabilization Post-shutdown surveys Create nuclear island • Install electrical power to SFP • Move old or install new security-related power Chemical decontamination of primary loop Large component removal SAFSTOR preparation SAFSTOR • Monitor systems and radiation levels • Preventive and corrective measures on SSCs

Table H-2. (contd)

Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontaminate pipes in walls • High-pressure water sprays • Remove contaminated soil • Preventive and corrective maintenance on SSCs System dismantlement Structure dismantlement Entombment • Install engineered barriers • Disconnect operational systems • Remove radioactive material from outside of containment • Place material inside containment • Lower containment ceiling (optional) LLW packaging and storage Transportation • Large components • LLW License Termination Activities
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Activities resulting in occupational doses to workers - SMALL Activities resulting in dose to the public - SMALL The long-term radiological aspects of Rubblization or onsite disposal of slightly contaminated material would require a site-specific analysis and would be addressed at the time the license termination plan is submitted.

Table H-2. (contd)

Radiological Accidents (4.3.9)
Activities that Could Impact Radiological Accidents
Remove Fuel Organizational changes • Adjust site training Stabilization • Drain and flush system Chemical decontamination of primary loop Large component removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontamination inside pipe walls • High-pressure water sprays System dismantlement Structure dismantlement • Remove structures necessary for plant operations Entombment • Lower containment ceiling (optional) LLW packaging and storage Transportation • Large components • LLW
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Activities resulting in accidents with offsite dose consequences - SMALL

Table H-2. (contd)

Occupational Issues (4.3.10)
Activities that Could Have Occupational Impacts
Remove fuel Organizational changes • Adjust site training Stabilization Create nuclear island • Install electrical power supply • Install or modify chemistry controls • Move old or install new security-related power Chemical decontamination of the primary loop Large component removal SAFSTOR preparation Storage (SAFSTOR) • Do preventive and corrective maintenance on SSCs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontaminate piping inside walls • High-pressure water sprays of surface • Remove contaminated soil System dismantlement • Do preventive and corrective maintenance on SSCs Structure dismantlement Entombment Low-level waste packaging and storage Transportation • Large components • LLW License termination activities • Complete final radiation survey
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to occupational noise, temperature, ergonomic, and biological hazards if proper ES&H procedures are followed - SMALL

Table H-2. (contd)

Cost (4.3.11)
Activities that Could Have Socioeconomics Impacts
Removal Fuel • Drain primary system • Process liquid Organizational changes Stabilization Post-shutdown surveys Create nuclear island • Install electrical power to SFP • Reduce security area • Change security function • Move old or install new security-related power Chemical decontamination of primary loop Large component removal SAFSTOR preparation SAFSTOR Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation License Termination Activities
Generic
No - Decommissioning costs are site specific
Impact and Summary of Findings
NA – Evaluation of decommissioning cost is not a NEPA requirement. This information is presented as a summary of actual and predicted decommissioning costs based on available data.

Table H-2. (contd)

Socioeconomics (4.3.12)
Activities that Could Have Socioeconomics Impacts
Organizational changes • Reduce staff • Employ contractor or other additional staff
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities and reactor types - SMALL

Table H-2. (contd)

Environmental Justice (4.3.13)
Activities that Could Impact Environmental Justice
Organizational changes • Reduce staff • Employ contractor or other additional staff Transportation • Large components • LLW
Generic
No - Requires a site-specific analysis. The impacts depend on the location of and circumstances of minority and low-income populations in the vicinity of the plant.
Impact and Summary of Findings
A site-specific analysis is required. The licensee must provide, in their PSDAR submittal, appropriate information related to the issue of environmental justice.

Table H-2. (contd)

Cultural and Historic Impacts (4.3.14)
Activities that Could Have Cultural Impacts
Stabilization Large Component Removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas
Generic
Yes - For activities within the operational area and reactor types
No - Requires a site-specific analysis if the activities are outside the boundaries of operational areas.
Impact and Summary of Findings
Activities are within the boundaries of the operational areas - SMALL
Activities are outside the boundaries of the operational areas - site specific

Table H-2. (contd)

Aesthetic Issues (4.3.15)
Activities that Could Have Aesthetic Impacts
Structure dismantlement Entombment • Install engineered barriers • Entomb facility in concrete
Generic
Yes - For all decommissioning activities
Impact and Summary of Findings
Visual intrusion would be temporary and would serve to reduce the aesthetic impact of the site for most decommissioning activities - SMALL

Table H-2. (contd)

Noise (4.3.16)
Activities that Could Have Noise Impacts
Structure dismantlement Entombment • Install engineered barriers • Remove radioactive structures outside containment • Entomb facility in concrete
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Noise levels are easily controlled during most decommissioning activities - SMALL

Table H-2. (contd)

Transportation (4.3.17)
Issues that Could be Impacted by Transportation Activities
Air Quality Radiological Radiological accidents Cost Environmental justice Irretrievable resources
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities, both radiological and nonradiological, related to transportation that are identified in this Supplement - SMALL

Table H-2. (contd)

Irretrievable Resources (4.3.18)
Activities that Could Impact Irretrievable Resources
System dismantlement Structure dismantlement LLW packaging and storage Transportation • Large components • LLW • Backfill trucked into site • Nonradioactive waste
Generic
Yes - For all decommissioning activities
Impact and Summary of Findings
All activities and options related to irretrievable resources - SMALL

Appendix I

Radiological Accidents

Appendix I

Radiological Accidents

The information below summarizes the review of existing information on accidents at decommissioning nuclear power facilities using the DECON or SAFSTOR option. The ENTOMB option was not included in this review because of the lack of available information; however, accidents would likely be similar to the DECON option during preparation of the facility for entombment. The purpose of this review was to determine the potential accidents that could occur at nuclear power facilities that have permanently ceased operations. When available, the potential offsite doses from these accidents were analyzed to determine which accidents could have the greatest offsite impact. This appendix provides an assessment of the activities conducted during decommissioning and determines whether accidents of greater consequence may occur during those activities.

As indicated in the Introduction to this Supplement, although the staff relies on the Commission's Waste Confidence Proceeding Finding, which states, in part, that there is, "reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant impact for at least 30 yrs beyond the licensed life for operation...of that reactor at its spent fuel storage basin..." (54 Federal Register 39767),[a] the staff has elected to include in this Supplement a discussion of potential accidents related to the storage and maintenance of fuel in a spent fuel pool.

Three sources of information were reviewed to obtain a list of potential accidents and their consequences: (1) U.S. Nuclear Regulatory Commission (NRC) research efforts, including NUREGs, NUREG/CRs, and the 1988 GEIS (NRC 1988), (2) industry-related publications and documents, and (3) licensing-basis documents for the individual plants, such as post-shutdown decommissioning activity reports (PSDARs), decommissioning plans, final safety analysis reports (FSARs) or FSAR-equivalent documents, or environmental reports (ERs) developed by the licensee. A list of documents used for this analysis is provided in Section I.5. Included as well were environmental assessments (EAs), environmental impact statements (EISs), safety evaluations, or emergency exemptions that were written by NRC. Twenty of the 22 plants listed in Chapter 3 were included in the analysis, which was completed in late 1999. Zion, Units 1 and 2, the most recent plants to permanently cease operations, were not included. |

(a) The Commission reaffirmed this finding of insignificant environmental impacts in 1999. This finding is codified in the Commission's regulations in 10 CFR 51.23(a).

I.1 Potential Accidents Considered During Decommissioning

Table I-1 contains a list of the accidents that were considered for both pressurized water reactors (PWRs) and boiling water reactors (BWRs) during decommissioning in early studies on safety and the cost of decommissioning PWRs and BWRs (Smith et al. 1978 and Oak et al. 1980, respectively). Both documents also considered several other types of accidents that were determined to be either of low probability or to result in very small releases, as shown in Table I-2. These accidents are listed along with a brief description or discussion of the accidents, as given in Smith et al. (1978) and Oak et al. (1980). The discussion in this section does not evaluate whether the accidents described in Smith et al. (1978) or Oak et al. (1980) should still be considered appropriate to the decommissioning process. As a result of improvements in the technology used for decommissioning, several of the accidents listed in Table I-2 may now be considered to be of a much lower probability or, at the least, to result in much-reduced consequences. For example, the use of a single failure-proof crane significantly reduces the potential for certain postulated spent fuel cask drops or heavy load accidents. Table I-3 provides a comprehensive list of accidents of potential accidents at facilities undergoing decommissioning, including HTGRs and FBRs.

The 1988 GEIS (NRC 1988) also considered accidents that could potentially occur during decommissioning. The list of postulated accidents was developed from the lists given in Smith et al. (1978) and Oak et al. (1980). However, not all accidents contained in these two documents were included in the 1988 GEIS, as shown by the footnote in Table I-1.

The staff conducted a study of spent fuel pool accident risk at decommissioning nuclear power facilities to support development of a risk-informed technical basis for reviewing exemption requests and a regulatory framework for integrated rulemaking (NRC 2001). Earlier analyses in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pools in Support of Generic Issue 82*, (Sailor et al. 1987) and NUREG/CR-6451, *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants* (Travis et al. 1997) included a limited analysis of the offsite consequences of a severe spent fuel pool accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed a further, analysis of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents. The external event initiators included:

- seismic events (earthquakes)
- aircraft crashes
- tornadoes and high winds

Table I-1. Summary of Accidents for PWR and BWR Plants Undergoing Decommissioning Operations[(a)]

Pressurized Water Reactors	Boiling Water Reactors
Explosion of liquid propane gas leaked from a front-end loader – Explosion ruptures filters and prefilters in the purge exhaust filter banks in containment.	**Explosion of liquid propane gas leaked from a front-end loader** – Used to load concrete rubble in the reactor building Assumed to occur in building ventilation ductwork and to cause failure of filters and blowers as well as to release radioactive contamination that is deposited on the high-efficiency particulate air (HEPA) filters and in the ductwork
Explosion of oxyacetylene during segmentation of the reactor pressure vessel – Postulated during segmenting of the reactor pressure vessel in the reactor cavity. Explosion is sufficient to cause failure of the HEPA filter in the contamination control envelope.	**Oxyacetylene explosion** – During use of oxyacetylene cutting torch to remove the activated portion of the reactor vessel in air before segmenting the removed sections under water.
Explosion and/or fire in the ion exchange resin – Explosive release of an ion exchange column in a nuclear waste facility.	--
Detonation of Unused Explosives in the Reactor Cavity[(b)] – A charge used to scarf the bioshield is detonated when the water spray is turned off, and the blasting mat and contamination control envelope are not in place.	**Detonation of unused explosives** – Assumes that a charge positioned to remove the sacrificial shield explodes when the water sprays are off and the contamination control envelope has been removed.
Fire in contaminated sweeping compound[(b)] – Sweeping compound is composed of sawdust treated with oil or other additives to enhance pickup of contamination. Postulated to catch fire spontaneously. Contains contamination from the floor surfaces	**Contaminated sweeping compound fire** – Sweeping compound is composed of sawdust treated with oil or other additives to enhance collection of loose surface contamination. A fire is postulated to occur in used sweeping compound contaminated with radioactive material.
Gross leak during *in situ* decontamination – Leak of 10 times the magnitude of the routine *in situ* decontamination leak for 30 minutes.	**Gross leak during loop chemical decontamination** – A massive failure of reactor piping during loop chemical decontamination is assumed to be low. This accident involves a gross leak about 10 times larger than the spray lead. A total of 1% of the liquid in the system is assumed to be made airborne.
Segmentation of reactor coolant system (RCS) piping with unremoved contamination – Released to the reactor containment building since no contamination-control envelope is assumed to be used.	–

Table I-1. (contd)

Pressurized Water Reactors	Boiling Water Reactors
Loss of contamination control envelope during oxyacetylene cutting of the reactor vessel shell – Molten metal particles penetrate the plastic sheet walls. Release lasts 5 minutes.	**Contamination control envelope rupture** – During oxyacetylene cutting. Molten metal particles penetrate the plastic sheet walls and increase leakage into the reactor building. Assumed to occur during the removal of the reactor vessel. Assumed large leak occurs for 1 hour of cutting before it is detected.
Pressure surge damage to filters during blasting of activated concrete bioshield[b]	**Filter damage from blasting surges** – During removal of activated concrete in the sacrificial shield.
Loss of blasting mat during removal of activated concrete[b] – Protective blasting mat is lost during blasting, and confinement barriers could be breached.	--
Temporary loss of local airborne contamination control during blasting[a] – A contamination control envelope is required in the reactor containment building during the explosive removal of the contaminated concrete in the biological shield. Loss of fine fog spray and contamination control increases the dust made airborne.	--
Loss of integrity of portable filtered ventilation enclosure during segmentation of the steam generators[b] – Substantial breach occurs and is readily apparent. Segmenting is promptly terminated. Air flow continues for 10 minutes.	--
Vacuum bag rupture – Metal shards rupture the filter bag and puncture the vacuum cleaner, releasing all the collected material into the air.	**Vacuum filter-bag rupture** – From metal shard, releasing all collected material to the reactor building.
Fire involving contaminated clothing or combustible waste[b] – Assumed 1 m^3 (35 ft^3) of combustible waste (absorbent materials such as rags or paper wipes).	**Combustible waste fire** – Assumed 1 m^3 (35 ft^3) of combustible waste (absorbent materials such as rags or paper wipes).
Accidental cutting of contaminated piping – Caused by human error. Assumed pipe is 25 cm (10 in.) or smaller.	--
Accidental spraying of concentrated contamination with the high-pressure spray – Postulated to be in the thermal insulation that has hidden a slow leak for a number of years. Results in an airborne release.	–

Table I-1. (contd)

Pressurized Water Reactors	Boiling Water Reactors
Accidental break of contaminated piping during inspection[b] – Occurs during SAFSTOR in reactor building. Pipe is weakened by corrosion and becomes damaged by incidental jostling or hitting of pipe. Assumed not to have been decontaminated *in situ*. Ventilation system is not operating.	--
Minor accidents with closed van	**Minor transportation accident** – Truck collision or overturn with waste containers that may rupture, or a collision and overturn with a minor fire (½ hour or less) involving one Type A waste container.
Moderate accidents with closed van	--
Severe accidents with closed van	**Severe transportation accidents** – Truck collision or overturn and a major fire (1 hour or longer) involving 40 Type A waste containers.

(a) All accidents listed are from Smith et al. (1978) and Oak et al. (1980).
(b) These accidents were not included in the 1988 GEIS (NRC 1988).

- compression or buckling of stored assemblies from the impact of a dropped heavy load (such as a fuel cask)

- loss of neutron absorber plates that separate the stored assemblies.

The results of the staff's analysis is presented in Section I.2.

The accidents and malfunctions considered in licensing documents were divided into subgroupings within five main categories:

- fuel-related accidents, which center around the storage of fuel in the spent fuel pool

- other radiological, non-fuel-related accidents, which include onsite accidents related to decontamination or dismantlement activities (e.g., material-handling accidents or accidental cutting of contaminated piping), or storage activities (e.g., fires or ruptures of liquid waste tanks)

- external events, which include aircraft crashes, floods, tornadoes and extreme winds, earthquakes, volcanic activity, forest fires, lightning storms, freezing, and intruder events

Table I-2. Accidents Considered but Not Evaluated in Smith et al. (1978) and Oak et al. (1980)

Pressurized Water Reactors	Boiling Water Reactors
Accidents involving fuel – Extensively studied and considered in other references. Not unique to or amplified by decommissioning.	--
Temporary loss of local airborne containment control during jackhammer scarfing of concrete surfaces – Manual operation, so the loss of local airborne containment is readily apparent to operator. Operation is suspended before significant release occurs.	--
Dropping of contaminated concrete rubble – Causing fine particles to become suspended in air. Quantity of such material is assumed to be small since most of the readily suspendible particles are removed during routine operations.	--
Dropping a concrete slab during placement in onsite retrievable waste storage – Precast concrete slab used for top shield and sealing surface is dropped 6 m (20 ft) while it is being placed. Surface particles become airborne, but do not increase routine release significantly and are not considered further in this study.	--
--	**Ion-exchange resin accidents** – Assumes no danger of combustion. Handling accidents appear likely, but would lead to little airborne release because of liquid nature of wastes involved.
Temporary loss of services, such as water, power, or airflow – Constitutes a lesser hazard for airborne releases than other postulated accidents.	**Loss of services, such as water supply, electrical power, or air flow** – Constitutes a lesser magnitude release than other postulated accidents, so no further analysis was made.
Natural phenomena – Reference PWR is designed to withstand effects of natural phenomena. It is assumed that this structural integrity is preserved during decommissioning as long as required for safety. These are low-probability events, e.g., floods, earthquakes, tornadoes, and high winds.	**Natural phenomena** – Reference BWR is designed to withstand the most severe natural phenomena recorded for the site with appropriate margins for uncertainties. Events are of low probability, and impact is less than the impacts calculated for operating BWRs. Includes floods, earthquakes, tornadoes, and high winds.
Aircraft crashes – Probability is low, risk is not escalated by dismantlement operations.	**Aircraft crashes** – Probability is low and risk of damage is low and not escalated by dismantlement operations.
--	**Man-caused events** – Covers wide spectrum of magnitude, ranging from releases induced by casual trespassers to releases induced by armed terrorists. Detailed analysis beyond scope of study.

- offsite events, which consist solely of transportation accidents that occur offsite
- hazardous, nonradiological, chemical-related accidents, with the potential for injury to the offsite public either directly from the accident, or as a result of further actions initiated by the accident.

Table I-3 contains the list of accidents as described in the licensing documentation for each of the 20 plants reviewed. The accidents are organized under the five category headings shown above and under subgroup headings that describe a specific type of accident, e.g.,"cask or heavy load handling accidents" or "spent resin accidents." Each of the plants described the accidents they evaluated in a specific way, which may or may not be identical to the subgroup headings. For example, Big Rock Point considered a "loss of spent fuel pool cooling," while the Trojan Nuclear Plant described a similar accident as a "loss of spent fuel decay heat removal without concurrent spent fuel pool inventory loss." The exact descriptions given by the plants were used when available. In some cases, however, a short description was not available, and it was necessary to paraphrase or summarize from a longer discussion of the accident.

Categorizing accidents is not a straightforward process. Frequently, an initiating event causes more than one type of accident. For example, the loss of electric power could cause the loss of spent fuel cooling, resulting in the potential for fuel failure and subsequent offsite release. The same loss of electric power could result in a crane or hoist failure, resulting in a heavy object being dropped either into the spent fuel pool with subsequent failure of fuel cladding, or in a highly contaminated object other than fuel being dropped onto an unyielding surface, causing the release of contamination. The same loss of electric power could affect the ventilation system and result in the loss of high-efficiency particulate air (HEPA) filtration and subsequent release of contamination. Alternatively, a single accident could be caused by multiple types of initiating events. For example, the loss of spent fuel pool coolant could be caused by the loss of offsite power, a break in a pipe (resulting from cutting the wrong pipe), or an external event (such as damage to the pipes from freezing or rupture of the pool during an earthquake) causing the release of the water. Because an effort was made to categorize the accidents as they were described by the licensing documents for each plant, a "loss of offsite power accident" may be the same thing as a "loss of spent fuel cooling accident." In some cases, a single plant would analyze both the loss of offsite power and the loss of spent fuel pool cooling as separate accidents, whereas they both concluded with the same result.

Table I-3. Comprehensive Accident List

Fuel-Related Accidents	Nuclear Plant
Cask or Heavy Load Handling Accident	
Cask drop into spent fuel pool	Haddam Neck
Spent fuel shipping cask drop in the spent fuel pool	Maine Yankee
Spent fuel cask drop	San Onofre, Unit 1
Shipping cask or heavy load drop in fuel element storage well	La Crosse
Heavy load drop (equivalent to spent fuel cask drop) into pool	Big Rock Point
Drop of heavy object (cask) into spent fuel pool	Indian Point, Unit 1
Heavy load drop (equivalent to spent fuel cask drop) into spent fuel pool	Humboldt Bay, Unit 3
Heavy load drop	Fort St. Vrain
Spent Fuel-Handling Accident	
Fuel assembly drop	Haddam Neck
Fuel-handling accident	Trojan
Fuel-handling accident	San Onofre, Unit 1
Fuel-handling accident	Rancho Seco
Spent fuel handling accident	Humboldt Bay, Unit 3
Spent fuel handling event	Yankee Rowe
Fuel-assembly handling accident in the spent fuel pool	Maine Yankee
Spent fuel handling accident in fuel element storage well	La Crosse
Loss of Spent Fuel Pool Cooling	
Loss of spent fuel pool cooling water (caused by loss of offsite power)	Big Rock Point
Loss of fuel pool cooling	Indian Point, Unit 1
Loss of spent fuel pool cooling water	Yankee Rowe
Loss of fuel element storage well cooling	La Crosse
Loss of prestressed concrete reactor vessel shielding water (after fuel has been removed)	Fort St. Vrain
Loss of spent fuel pool decay heat-removal capability	Maine Yankee
Loss of spent fuel decay heat-removal without concurrent spent fuel pool inventory loss	Trojan
Failure of auxiliary electrical systems related to fuel pool cooling	Dresden, Unit 1
Loss of offsite power; limited loss of spent fuel pool cooling	San Onofre, Unit 1
Nonmechanistic loss of cooling and airborne release	Humboldt Bay, Unit 3
Loss of Water from the Spent Fuel Pool	
Loss of spent fuel pool water level	Big Rock Point
Loss of spent fuel pool water (nonmechanistic; earthquake beyond design basis)	Haddam Neck
Loss of spent fuel pool water	Indian Point, Unit 1
Loss of spent fuel pool inventory (loss of heat sink or by inadvertent siphoning)	Maine Yankee
Loss of spent fuel pool water from pool rupture of unknown origin	Humboldt Bay, Unit 3
Loss of cooling water	Yankee Rowe
Fuel pool drain-down	Dresden, Unit 1

Table I-3. (contd)

Fuel-Related Accidents (contd)	Nuclear Plant
Fuel element storage well system pipe break	La Crosse
Loss of spent fuel pool decay heat-removal capability with concurrent spent fuel pool inventory loss	Trojan
Loss of Offsite Power	
Loss of offsite power (resulting in loss of spent fuel cooling)	Big Rock Point
Loss of offsite power (resulting in loss of water from the pool)	La Crosse
Loss of offsite power (resulting in loss of spent fuel pool cooling)	Rancho Seco
Loss of power	Fort St. Vrain
Temporary loss of offsite power (crane or hoist failure)	Trojan
100% Fuel Failure	
100% fuel failure	Indian Point, Unit 1
100% fuel failure	Shoreham
Simultaneous failure of fuel assemblies	Dresden, Unit 1
Criticality	
Inadvertent criticality (misplaced assembly in pool)	Maine Yankee
Criticality, stored spent fuel rearranged from seismic or other events	Humboldt Bay, Unit 3
Accidents Involving Radioactive Materials (Non-Fuel-Related)	
Decontamination-Related Accidents	
Spray release during in situ decontamination of systems	Saxton
Gross leak or accident during in situ decontamination (spray and liquid)	Trojan
Decontamination of liquid spill	Three Mile Island, Unit 2
Decontamination events	Yankee Rowe
Accidental spraying of concentrated contamination with high-pressure spray	Three Mile Island, Unit 2
Concentrated contamination spray	Three Mile Island, Unit 2
Radioactive Material (Non-fuel) Handling Accidents	
Waste container drop	Pathfinder
Waste container drop and rupture (containing activated concrete rubble)	Shoreham
Dropping of filters or packages of particulate material	Trojan
Dropping of contaminated components	Trojan
Dropping of concrete rubble	Fort St. Vrain
Dropping of concrete rubble	Trojan
Packaging events	Yankee Rowe
Materials-handling event	Yankee Rowe
Steam generator load drop inside containment	Trojan
Dropping the reactor pressure vessel	Pathfinder
Dropping steam generator primary module	Fort St. Vrain
Steam generator load drop outside of containment	Trojan

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Dismantlement-Related Accidents	
Contamination release during accidental cutting of contaminated piping	Three Mile Island, Unit 2
Contamination release during accidental break of contaminated piping	Three Mile Island, Unit 2
Loss of engineering controls during dismantlement of reactor cavity	Big Rock Point
Contamination release during dismantlement of main coolant system loop	Yankee
Dismantlement of RCS and safety injection piping without or with loss of local engineering controls	Saxton
Absence of blasting mat during removal of activated concrete	Trojan
Loss of HEPA Filters	
Rupture of contamination-control envelope; release of contamination on HEPA filter	Shoreham
HEPA filter failure	Three Mile Island, Unit 2
Loss of integrity of portable filtered ventilation enclosure	Trojan
Pressure-surge damage to filters during blasting of activated concrete bioshield	Trojan
Temporary loss of local airborne contamination control during blasting	Trojan
Temporary loss of local airborne contamination control during scarfing of contaminated concrete surfaces with jackhammer	Trojan
Loss of contamination-control envelope during oxyacetylene cutting of the reactor-vessel shell	Trojan
Radioactive Gas Waste System Leaks	
Leaks and failures in radioactive waste gas system in radwaste decay tanks	Maine Yankee
Leak or failure in radioactive waste gas system	Trojan
Radioactive Liquid Waste Releases	
Liquid waste tanks rupture	Fermi, Unit 1
Storage tank rupture	Three Mile Island, Unit 2
Liquid waste storage vessel failure	Saxton
Postulated radioactive releases due to liquid tank failures	Trojan
Liquid radioactive tank release	Humboldt Bay, Unit 3
Liquid radioactive waste release to lake through cracks in building, earthquake-induced	Fermi, Unit 1
Rupture of spent fuel pool, contents released to bay	Humboldt Bay, Unit 3
Liquid waste discharge pumped to river without sampling	La Crosse
Leaks and failures in radioactive liquid waste system	Maine Yankee
Condensate storage tank contents pumped into ground during in-service leak test (actual event report)	Dresden, Unit 1
Containment Breach (Open Penetration to Containment)	
Containment vessel breach, subsequent loss of contents to air/water	Saxton
Open penetration – unfiltered pathway from containment	Three Mile Island, Unit 2

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Release of helium coolant	Peach Bottom 1
Spent Resin Accidents	
Spent resin handling accident (exothermic reaction during dewatering)	Haddam Neck
Dropped resin vessel during removal from containment building	Saxton
Low-level waste storage accident (resin liner drop)	Maine Yankee
Release of resins from makeup and purification demineralizer	Three Mile Island, Unit 2
Storage of spent resins	Big Rock Point
Explosion and/or fire in ion exchange resins	Trojan
Vacuum Filter Bag Ruptures	
Vacuum filter bag rupture during decontamination of spent fuel pool floor	Saxton
Vacuum filter bag rupture during cleaning of the Reactor Building floor	Shoreham
Vacuum canister failure	Three Mile Island, Unit 2
Loss of Electric Power	
Loss of offsite power	Yankee Rowe
Loss of offsite power	Trojan
Loss of electric power with unknown scenario	Pathfinder
Loss of offsite power affecting HEPA filters, etc.	Saxton
Loss of Compressed Air	
Temporary loss of compressed air	Trojan
Loss of compressed air	Yankee Rowe
Fire	
Fire	Dresden, Unit 1
Fire	San Onofre, Unit 1
Fire	Fort St. Vrain
Fire	Indian Point, Unit 1
Fire events (primarily those that could impact SFP cooling)	Big Rock Point
Fire inside of containment	Three Mile Island, Unit 2
Fire inside reactor vessel	Peach Bottom 1
Fire inside stairwell	Three Mile Island, Unit 2
Fire in D-rings	Three Mile Island, Unit 2
Fire in reactor building or fuel handling building	Pathfinder
Fire in boiler building	Pathfinder
Fire in storage facilities	Yankee Rowe
Fire in intermodel container of waste	Yankee Rowe
Fire in combustible waste stored in yard	Saxton
Fire in low-level radioactive waste storage building	Trojan
Combustible waste fire in 208-L (55-gal) drum container	Shoreham
Contaminated clothing or combustible waste fire	Trojan

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Contaminated sweeping compound fire (sawdust with oil and other additives, used to enhance collection of loose surface contaminants)	Shoreham
Fire or other catastrophic event, initiator for residual sodium release	Fermi, Unit 1
Explosion	
Explosion of liquid propane gas leaked from front-end loader in containment	Trojan
Liquid propane gas explosion on front-end loader	Shoreham
Liquid propane gas explosion caused by an accidental leak on front-end loader used in containment building	Saxton
Oxyacetylene explosion in the containment building while cutting reactor coolant system piping and release of HEPA filter contents within portable enclosure	Saxton
Oxyacetylene explosion and release of HEPA filter contents	Shoreham
Explosion of oxyacetylene during segmenting of reactor vessel shell	Trojan
Explosion event inside vapor container	Yankee Rowe
Explosion inside area warehouse	Yankee Rowe
Explosion of large fuel-oil storage tanks	Humboldt Bay, Unit 3
Detonation of unused explosives in reactor cavity	Trojan
Sodium interaction with water caused by water inflow through a crack in a tank	Fermi, Unit 1
Onsite Transportation Accidents	
Onsite transportation accident	Yankee Rowe
Accidents Initiated in External Events	
Aircraft Crashes	
Aircraft hazards	Big Rock Point
Aircraft crashes	Trojan
Aircraft impact	Yankee Rowe
Floods	
Flood	San Onofre, Unit 1
Flood	Yankee Rowe
Flood	Pathfinder
Flooding	Saxton
External flooding	Big Rock Point
External flooding	Trojan
Site flooding	Dresden, Unit 1
Site flooding	Indian Point, Unit 1
Site flooding	Peach Bottom, Unit 1
Flood, seiches, and tsunamis	Shoreham
Low Water	
Probable minimum water level, from negative lake surge or sieche	Big Rock Point

Table I-3. (contd)

Accidents Initiated in External Events (contd)	Nuclear Plant
Wind	
Tornadoes and extreme winds	Pathfinder
Tornadoes and extreme winds	Trojan
Tornadoes and extreme wind	Yankee Rowe
Tornadoes and extreme wind	Saxton
Tornadoes and wind	Big Rock Point
Wind and tornadoes	La Crosse
Wind and tornado missiles	San Onofre, Unit 1
Tornados and hurricanes	Shoreham
Natural disaster, tornado	Fort St. Vrain
Earthquakes	
Earthquake	Big Rock Point
Earthquake	Indian Point, Unit 1
Earthquake	Pathfinder
Earthquake	Trojan
Earthquake	Saxton
Earthquake	San Onofre, Unit 1
Earthquake	Shoreham
Earthquakes	Yankee Rowe
Seismic events	Dresden, Unit 1
Seismic event	La Crosse
Volcanoes	
Volcanic activity	Trojan
Lightning	
Lightning	Trojan
Lightning	Saxton
Lightning	Yankee Rowe
Forest Fire	
Forest fires	Yankee Rowe
Forest or brush fire	Saxton
Freezing Temperatures	
Freezing temperatures, loss of plant heating	Big Rock Point
Freezing temperatures (actual accident)	Dresden, Unit 1
Physical Security	
Intruder event	Saxton
Physical security breach	Shoreham
Physical security breach	Pathfinder

Table I-3. (contd)

Offsite Transportation-Related Accidents	
Offsite transportation accident	Shoreham
Offsite transportation accident	Yankee Rowe
Transportation accident	Three Mile Island, Unit 2
Truck carrying radwaste – fire	Pathfinder
Truck and two intermodel containers, transportation accident with fire	Saxton
Reactor pressure vessel railroad accident and fire	Pathfinder
Reactor pressure vessel in the river during transportation by rail	Pathfinder
Offsite radiological event (shipment of radioactive materials)	Saxton
Hazardous Nonradiological Chemical Events	
Toxic chemical event (initiation for material handling event)	Saxton
Toxic chemical event	Trojan
Chemical combustion (from sodium-water interaction) and dispersal	Fermi, Unit 1
Toxic chemical event, initiator for fuel-handling event	Trojan

All accidents identified by licensees were included in Table I-3, even if they were just considered without a detailed discussion or analysis of the consequences. A number of accidents were initially considered, but were determined without further analysis to fall under one of the following categories:

- an accident that is not possible or probable – For example, a licensee might consider an aircraft impact as an accident, but state in their documentation that the probability of occurrence is low and, therefore, the accident is not analyzed further.

- an accident may occur, but not result in any type of consequence – For example, during consideration of a flood, the licensee might state that "flooding events do not result in significant radiological release; therefore, public health and safety are not adversely affected," or in the case of a material-handling event, make a statement such as, "compliance with management programs and quality assurance plan ensure that the probability of occurrence and the consequences do not significantly affect the public health and safety."

- an accident may occur, but mitigative actions can be taken before any radioactive material is released offsite – For example, during consideration of a seismic event, a statement is made that the facility was designed to accommodate the initiating event, and no damage resulting in a release would occur.

- an accident may occur, but with minimal offsite dose consequences – For example, loss of cooling for a spent fuel pool where the fuel has cooled to a level that would not result in the release of activity for a number of days and where mitigative actions could be taken to ensure that there would be no release of radioactive materials.

Although these accidents were not analyzed in depth, they were considered and, therefore, are included in Table I-3.
Most licensees did not describe the entire scenario that would cause the accident. For example, most documents that discussed the analysis of the release of liquid radioactive waste did not provide an indication of the event that caused the rupture of a liquid waste tank or storage tank. Therefore, it was a simple decision to place this accident in the group of "Liquid Radwaste Releases." However, some licensees did provide a complete scenario, such as a description that the tanks located in the basement were assumed to have been cracked during an earthquake, allowing fluid to leak into the earth and then into an aquifer, finally settling in a nearby lake. This accident could have been grouped by the initiating event (an earthquake) or the consequence (a release of liquid radioactive waste). In such cases, the initiators (or the consequences) are also shown in Table I-3.

In other cases, the accident could easily be placed under more than one heading. For example, one licensee (Trojan Nuclear Plant) analyzed an explosion and/or fire in the ion exchange resins. This accident could have been included under "Explosions," "Fires," or "Spent Resin Accidents." In this case, the last choice was selected. Another example would be the "oxyacetylene explosion and release of HEPA filter contents," which was analyzed by the licensees for the Saxton, Shoreham, and Trojan Nuclear Plants. This accident could have been included under either "Explosions" or "Loss of HEPA filters." In this case, the first choice was selected.

In some cases, the descriptions provide much more information regarding the accident than they do in other cases. For instance, under the heading "Fire," five of the licensees did not give any more detailed description other than they were analyzing a "fire" or "fire events." Other licensees described the location of the fire (inside stairwells, inside boiler buildings, etc.), and the remainder discussed the items that were combusted (contaminated clothing or waste, or contaminated sweeping compound).

Some of the descriptions of the accidents did not give any details regarding the scenario that resulted in offsite dose consequences. These accidents were described as nonmechanistic, i.e., they had no associated scenarios or initiators. For example, three licensees evaluated the simultaneous failure of 100% of the fuel assemblies in the spent fuel pool but gave no reason for the simultaneous failure.

The fuel-related accidents centered around the storage of the spent fuel in the spent fuel pool. The most common fuel-related accidents analyzed include the loss of spent fuel pool cooling (10 facilities), the loss of water in the spent fuel pool (9 facilities), cask or heavy handling (8 facilities), and the spent fuel handling (8 facilities). The accidents listed under "Loss of Offsite Power Accidents" also result in the loss of cooling, the loss of water from the pool, or a handling accident.

The non-fuel-related accidents center around decontamination, dismantlement, or storage-type activities. Decontamination-related activities include *in situ* decontamination and rupture of vacuum-filter bags. Accidents from these activities could include fires that occur in contaminated clothing or sweeping compounds. Dismantlement-related activities include accidental cutting or breaking of contaminated piping or breaching of containment, loss of HEPA filters during cutting or blasting operations, and material-handling accidents, such as dropping of contaminated components, concrete rubble, or spent resins. Dismantlement activities also include the potential for explosions either from front-end loaders or while using oxyacetylene during dismantlement activities. Storage-type activities include storage of non-fuel wastes that could result in liquid waste tank ruptures and explosive gas buildup in ion exchange resins. There is also the potential for fires in buildings or in waste stored inside the facility.

The most common non-fuel-related accidents that involved radioactive material were the fires (20 total accidents from 12 different plants). A fire may be one of the more important accidents to consider for a plant in decommissioning because of the large loading of combustible material resulting from the amount of low-level radioactive waste in the form of wipes, clothing, etc. Fire events included generic listings of "fire," specific listings of locations where the fire might occur (in the boiler building or low-level waste storage buildings) or the material the fire involves (contaminated clothing or contaminated sweeping compounds).

The second most common non-fuel-related accident related to the handling of radioactive (non-fuel) material such as waste containers, filters, concrete rubble, contaminated components, or larger items such as reactor pressure vessels or steam generators (13 accidents identified from 5 separate plants). The third most common radiation-related (non-fuel) accident was from explosions, which comprise 11 accidents from 5 separate plants. These accidents included explosion of liquid propane gas from front-end loaders being used for dismantlement activities and oxyacetylene explosions during dismantlement, which released HEPA filter contents, or during the reactor vessel shell. The fourth most common non-fuel-related accident is the release of liquid radioactive waste from storage tanks. The majority of these accidents resulted from the rupture or failure of a tank storing liquid radioactive waste. However, one of the postulated accidents occurs during the inadvertent pumping or transfer of the liquid radioactive waste to the river without sampling. Another of the postulated accidents in this group was the rupture of the spent fuel pool, with the contents released to a nearby body of water. This accident looked at the offsite dose consequences of the contaminated water being released to the environment and did not consider the resultant effect on the spent fuel remaining in the now-drained pool (considered a separate accident).

The licensees considered external events, including aircraft crashes into the facility's buildings, floods, low water levels, wind, earthquakes, volcanoes, lightning, forest fires, freezing temperatures, and physical security (intruder-initiated events). Earthquakes or seismic events (11 accidents from 10 plants), site flooding (10 accidents from 10 plants) and tornado or extreme wind (10 accidents from 9 plants) were the most commonly cited.
There is only one subgrouping of transportation-related accidents. Eight potential transportation-related accidents were discussed, ranging from transportation of low-level waste to transportation of large components, such as the reactor pressure vessel.

There were four accidents related to nonradiological, chemical releases that were found in the licensing-basis documentation. Three of the four accidents would result in an offsite release of toxic chemicals, and the fourth would result in a chemical event that would incapacitate the operator of a crane inside the plant, thus initiating a material-handling event.

I.2 Consequences of Potential Accidents

In addition to compiling a comprehensive list of accidents and malfunctions at permanently shutdown facilities, the potential offsite dose consequences were evaluated. The evaluation of dose consequences is necessary for understanding the risk to the public from these accidents. Compared to the potential consequences from an accident at an operating facility, most of the accident consequences for a permanently shutdown facility are small. This section addresses accident consequences both from the accidents obtained from NRC-sponsored research and the accidents found in the licensing documentation.

Table I-4 presents the highest doses in each of four categories of radiological accidents as obtained from licensing-basis documents. The highest doses result from postulated fuel-related accidents and radioactive-material-related accidents. All accidents that were reviewed used conservative assumptions to calculate the offsite dose. For example, some licensees analyzed accidents that considered the 100% failure of fuel by using assumptions that were non-mechanistic to determine the estimated dose.

Information obtained from licensing-basis documents for the fuel-related accidents showed that the highest doses were from the cask or heavy load handling accidents, the accidents that assumed a 100% fuel failure, and the spent fuel handling accidents. Although some of the licensing-basis documents gave calculated doses to the offsite population from the loss of water in the spent fuel pool (Maine Yankee, 2.3 mSv [0.23 rem]; Fort St. Vrain, 0.35 mSv [0.035 rem]) and from the loss of cooling capability to the spent fuel pool (Maine Yankee, 2.2E-5 mSv [0.002 mrem]), the majority of the documents stated that these accidents would result in no appreciable offsite dose because the accident could be mitigated before offsite-dose consequences could occur.

Table I-4. Highest Offsite Doses Calculated for Postulated Accidents in Licensing-Basis Documents

Accident Description	Nuclear Plant	Offsite Whole-Body Dose, rem
Fuel-Related Accidents		
Cask drop into spent fuel pool	Haddam Neck	0 418
Loss of spent fuel pool inventory (loss of heat sink or by inadvertent siphoning)	Maine Yankee	0.23
Shipping cask or heavy load drop into fuel element storage well	La Crosse	0.186
Loss of prestressed concrete reactor vessel shielding water (after fuel has been removed)	Fort St. Vrain	0.035
100% fuel failure	Indian Point, Unit 1	0.027
Simultaneous failure of fuel assemblies	Dresden, Unit 1	0.016
Spent fuel handling accident	Humboldt Bay, Unit 3	0 013
Fuel-handling accident	Rancho Seco	0.01
Heavy load drop	Fort St. Vrain	0 007
Fuel assembly drop	Haddam Neck	0 0026
Radioactive Material-Related Accidents (Non-Fuel)		
Spent resin handling accident (exothermic reaction during dewatering)	Haddam Neck	0 96
Explosion inside vapor container	Yankee Rowe	0.44
Radioactive liquid waste system leaks and failure	Maine Yankee	0.23
Materials-handling event	Yankee Rowe	0.16
Fire	Fort St. Vrain	0.12
Fire in intermodal container of waste	Yankee Rowe	0.1
Fire in D-rings	Three Mile Island, Unit 2	0 049
Decontamination events	Yankee Rowe	0 039
Liquid radioactive waste released to lake through cracks in building (earthquake-induced)	Fermi, Unit 1	0 02364
Release of resins from makeup and purification demineralizer	Three Mile Island, Unit 2	0 02
External-Events Initiated Accidents		
Natural disaster, tornado	Fort St. Vrain	0.001
Physical security breach	Pathfinder	<0 000001
Offsite Transportation Accidents		
Reactor pressure vessel railroad accident and fire	Pathfinder	0.00014
Truck carrying radioactive waste – fire	Pathfinder	0.000005
Reactor pressure vessel drop into river during transportation by rail	Pathfinder	0.000001
Transportation accident	Three Mile Island, Unit 2	<0.000001

To convert from rem to sievert, multiply by 0 01.

In addition to the licensing-basis documents reviewed, the staff's report *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants* report (NRC 2001) provides an analysis of the consequences of the spent fuel pool accident risk. As discussed previously, earlier analyses in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pools in Support of Generic Issue 82*, (Sailor et al. 1987) and NUREG/CR-6451, *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants* (Travis et al. 1997) included a limited analysis of the offsite consequences of a severe spent fuel pool accident occurring up to 90 days after the last discharge of spent fuel into the spent fuel pool. These analyses showed that the likelihood of an accident that drains the spent fuel pool is very low, although the consequences of such accidents could be comparable to those for a severe reactor accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed a further analysis of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents using fission product inventories at 30 and 90 days and 2, 5, and 10 years. The accident progression scenarios that lead to large radiological releases following the drainage of a spent fuel pool require many nonmechanistic assumptions. This is because the geometry of the fuel assemblies, and the air cooling flow paths, cannot be known following a major dynamic event that might drain the water from the spent fuel pool. In addition, no credit is taken for preventative or mitigative actions and large uncertainties exist in the source term and consequence calculations. Because of these uncertainties, the staff developed bounding risk curves in NUREG-1738 (NRC 2001) that capture both the frequency and consequences of a beyond-design-basis spent fuel pool drainage event. The risk curves are provided in Figures I-1 and I-2. The results of the study indicate that the risk at spent fuel pools is low and well within the Commission's Quantitative Health Objectives. The risk is low because of the very low likelihood of a zirconium fire even though the consequences from a zirconium fire could be serious.

For the "Other Radioactive Material-Related" accidents (nonfuel), the accident subgroup with the highest estimated offsite dose was 0.96-rem total effective dose equivalent (TEDE) for a spent resin handling accident. The spent resin handling accident is only slightly below the U.S. Environmental Protection Agency's Protective Action Guide (PAGs). Other associated accident scenarios included handling accidents occurring during dewatering, releases from makeup and purification demineralizers, and the dropping of liners. Other categories with significant estimated doses include accidental releases of radioactive liquid wastes, radioactive material (nonfuel) handling accidents, explosions, and fires. However, there was a significant variation in doses within each subcategory. For example, for the radioactive liquid waste release accidents, the estimated doses range from a high of 2.3 mSv (0.23 rem) TEDE for a leak in the radioactive liquid waste system (Maine Yankee) to an estimate of "no dose" for the uncontrolled liquid waste discharge via a tank pumped directly to the river (Humboldt Bay 3).

The external event accidents (aircraft crashes, forest fires, floods, freezing temperatures, low water levels, lightning, earthquakes, volcanoes, and extreme winds and tornadoes) were in all but one case determined by the licensee's analyses either to be of a very low probability of occurrence, to have no dose consequences, to have doses that were bounded by other accidents, or to have doses that were below the U.S. Environmental Protection Agency (EPA) PAGs (EPA 1991). Most of the time, it was indicated that the doses would be significantly less than the EPA PAGs. The one case where an offsite dose was calculated was a tornado event (Fort St. Vrain), which was estimated to result in a whole body, 2-hour dose of 0.0058 mSv (0.0058 rem) and an organ dose (lung) of 0.17 mSv (0.017 rem).

Doses from offsite transportation accidents were very small, ranging from a "no dose" estimate to an estimated 0.0014 mSv (0.00014 rem) for a reactor pressure vessel that was involved in a railroad accident (Pathfinder).

The accident consequences during decommissioning are somewhat time-dependent since some of the radionuclide inventory significantly decreases shortly following shutdown, and then continues to decrease at a slower rate during the entire decommissioning period. This is most pronounced for the fuel-related accidents since some of the radionuclides present in the fuel, such as iodine-131, have a significant impact on the severity of the dose, but have a short half-life and will decay to negligible amounts within a few months following shutdown.

I.3 Correlation of Activities with Potential Accidents During Decommissioning

Activities and hazards at reactor sites following permanent shutdown and defueling may be different from those routinely experienced at an operating reactor; however, there are similarities in decommissioning activities and the activities that take place during refueling and maintenance outages.
Table I-5 lists the activities that characterize the type of actions that are being taken at sites both in DECON and SAFSTOR and compares the activities to the accidents listed in Table I-3, "Comprehensive Accident List." This list of activities was obtained from documentation from the

sites that have recently completed, or have recently started, the decommissioning process. The list is divided into activities performed during DECON and SAFSTOR. The decontamination and dismantlement activities were included for those sites that are in SAFSTOR but are performing incremental decontamination and dismantlement. Under DECON, the activities are categorized as having to do with construction; decontamination; contamination control; dismantlement; removal of the vessel, internals, and other large components and systems; radioactive waste management; spent fuel pool; soil remediation;

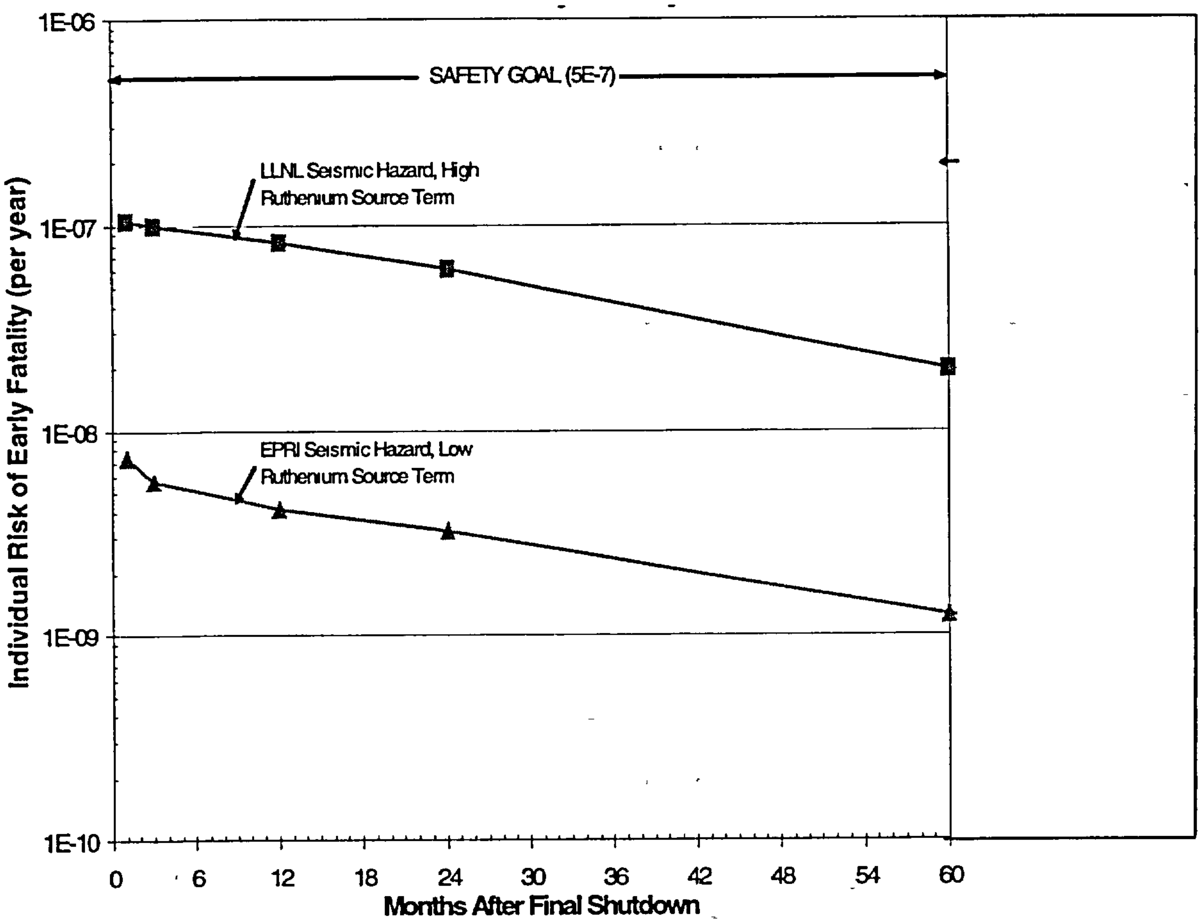

Figure I-1. Individual Early Fatality Risk Within 1 Mile of the Plant After a Beyond-Design-Basis Spent Fuel Pool Drainage Event.

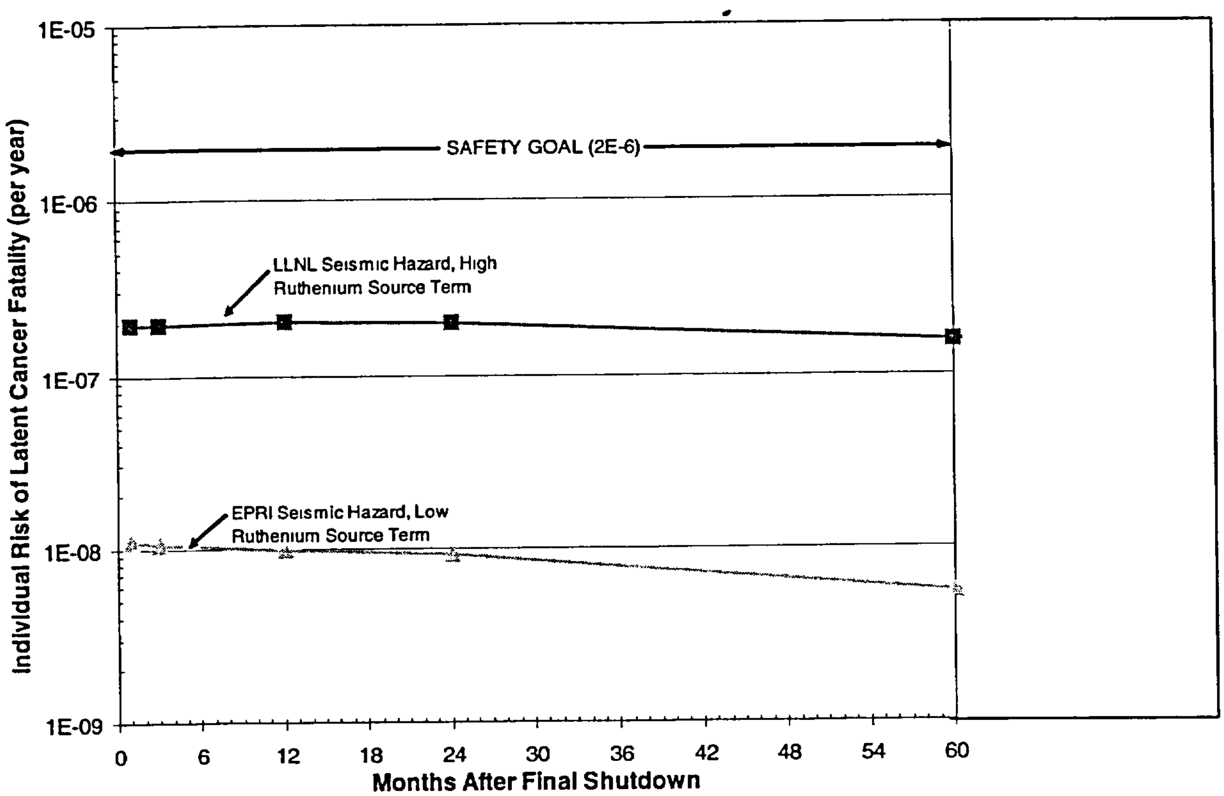

Figure I-2. Individual Latent Cancer Fatality Risk Within 10 Miles of the Plant After a Beyond-Design-Basis Spent Fuel Pool Drainage Event.

and the final radiation survey. For activities that take place during SAFSTOR, activities are simply listed as taking place in preparation for or during SAFSTOR.

For each activity, an assessment was made to determine the accident type that might occur during that activity. In the right-hand column of Table I-5, an associated accident is given, using the subgroup heading used in Table I-3. If an activity was determined not to have the potential for an accident, then it is described as "no accident." From the comparison of activities to accidents, it was determined that there would be no accident of greater consequence than the accidents already identified.

Table I-5. Comparison of Activities and Accidents During DECON and SAFSTOR

Activities	Associated Accidents
DECON	
Construction and Establishment	
Possible establishment of site construction power site	No accident
Possible establishment of monitoring stations separate from the control room	No accident
Possible construction of independent spent fuel storage installation (ISFSI)	Cask or heavy load handling
Possible establishment of spent fuel pool cooling system that is independent of existing plant systems	Loss of spent fuel cooling
Possible construction of decommissioning support building and utilities	No accident
Possible establishment of radioanalytical facilities	No accident
Possible design and fabrication of special shielding and contamination-control envelopes	No accident
Possible establishment of radiological monitoring stations	No accident
In situ chemical decontamination of primary coolant system	Decontamination-related accidents
Decontamination of outside of large components, facility surfaces, components, and piping surfaces	Decontamination-related accidents
Vacuuming	Vacuum filter bag ruptures
Ultra-high-pressure water lancing	Decontamination-related accidents
Abrasive grit blasting	Decontamination-related accidents
Manual decontamination techniques (handwriting), wet mopping, scrubbing	Decontamination-related accidents
Painting or applying coatings to stabilize contamination	No accident
Contamination Control	
Bag items to prohibit contamination spread	Fire
Dismantlement	
Remove contaminated piping and tubing - cut and install covers and plugs	Dismantlement-related accidents; fire; hazardous materials accidents
Remove walls	Radioactive material (nonfuel) handling accidents
Demolish buildings	Radioactive material (nonfuel) handling accidents
Concrete removal with impact hammers, saw cutting, and diamond wire cutting	Radioactive material (nonfuel) handling accidents
Abrasive water jet cutting (scabbier) for concrete.	Decontamination-related accidents
CO_2 blasters for concrete	Decontamination-related accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Metal component dismantlement - saw cutting - power band saws - diamond wire saws - machining - mechanical shearing - manual disassembly - abrasive shell cutting - OD milling machines - torch cutting (thermal methods melt or vaporize surfaces of materials being cut)	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Rigging used to remove heavy or awkward sections Small-diameter piping	Radioactive material (nonfuel) related accidents; dismantlement-related accidents
Filings collected in catch basins and vacuumed, as needed	Radioactive material (nonfuel) related accidents; vacuum filter bag rupture
Removal of Reactor Pressure Vessel and Internals	
Piping and instrumentation lines cut; interferences removed	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Decontaminated, segmented, packaged, and shipped offsite – segmenting included underwater semi-automatic plasma arc and metal disintegration machining equipment	Decontamination-related accidents; radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Remove intact or segment	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Intact removal requires - opening in building - grouting of openings created by cutting operations - removal from containment and placement in lay down area - removal of internals - injection of grout into reactor vessel - installation of welded closure caps on all openings - installation of structural members, as necessary - potential welding around reactor vessel.	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; containment breach accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Removal of Other Large Components (Steam Generators and Pressurize)	
Intact removal or partial segmentation	Dismantlement-related accidents; radioactive material (nonfuel) handling accidents
Cut piping attachments	Dismantlement-related accidents; radioactive material (nonfuel) handling accidents; fire; hazardous materials accidents
Install temporary supports, cut hanger rods	No accidents given
Decontaminate external surfaces	Decontamination-related accidents
Seal-weld openings	
Move vessels horizontally for lifting through removable hatch or new opening in concrete building	Radioactive material (nonfuel) related accidents
Grout if required or segment greater than class C (GTCC) components for storage with the spent fuel	Dismantlement-related accidents; radioactive material (fuel- and nonfuel-related accidents)
Reactor Coolant System	
Decontaminate, segment, and dispose of RCS and other larger-bore piping	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Remove and package asbestos insulation	Nonradioactive hazardous materials accidents
Remove turbine control oil	Fire
Remove nonradioactive materials, including fuel oil, lubricating oil, 1,1,1-tricholorethane, laboratory chemicals, lead, mercury, paint, battery acid, asbestos	Fire; nonradioactive hazardous materials accidents
Radwaste Management	
Ship radioactive materials	Transportation accidents
Ship mixed wastes to approved disposal sites	Transportation accidents
Spent Fuel Pool	
Remove spent fuel and GTCC waste	Cask or heavy load handling accidents; spent fuel pool handling accidents
Decontaminate and dismantle spent fuel facility after all spent fuel has been removed	Decontamination-related accidents; dismantlement-related accidents; radioactive material (nonfuel) related accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Soil remediation	Radioactive material (non-fuel) related accidents
Final radiation survey	No accidents
SAFSTOR	
Preparation for SAFSTOR	
Assess functional requirements for all plant systems, structures, and components for all phases of decommissioning	None
Deactivate systems; dispose of nonessential structures and systems	Radioactive material (nonfuel) related accidents; fire; hazardous materials accidents
Drain and flush plant systems	Decontamination-related accidents; hazardous materials accidents
Decontaminate, as necessary	Decontamination-related accidents
Either lay-up or isolate plant systems, structures, and components no longer required	No accidents
Remove filter elements and demineralizer resin beds	Spent resin accidents
Wet-mopping of clean areas	No accidents
Process, package, and ship liquid and solid radioactive waste generated during plant closure activities	Radioactive material (nonfuel) related accidents; radioactive liquid waste-release accidents; transportation accidents; hazardous materials accidents
Install permanent safety-related electrical power supply to spent fuel pool cooling system	Spent fuel pool cooling accidents
Establish a permanent reactor coolant system vent path (permanent passive venting of RCS to containment atmosphere)	Loss of HEPA filters; fire
Establish a permanent containment vent path	Loss of HEPA filters; fire
Removal of nitrogen gas cylinders	No accidents
Reconfigure the instrument/service air system	No accidents
Make electrical modifications required to de-energize equipment	No accidents
Remove dedicated safe-shutdown diesel and generator	Fire; hazardous materials accidents
Perform an assessment of current radiological conditions	No accidents
SAFSTOR Activities and Tasks	
24-hour guard force	No accidents
Maintain environmental and radiation monitoring program	No accidents
Preventative and corrective maintenance on operating/functional plant systems, structures, and components	No accidents
Maintain structural integrity	No accidents
Process liquid radwaste	Radioactive liquid waste releases
Provide for safe spent fuel storage	Loss of spent fuel cooling accidents

Table I-5. (contd)

Activities	Associated Accidents
SAFSTOR (contd)	
Maintain security systems	No accidents
Maintain radwaste systems	Radioactive gas waste system leaks radioactive liquid waste releases
Maintain heating and ventilation, where necessary	No accidents
Maintain lighting, fire protection, heating, ventilation, and air conditioning, and alarm systems, as required	No accidents
Dispose of nonradioactive hazardous waste	Hazardous materials accidents
Remove unused equipment during SAFSTOR	No accidents
Operate and monitor required systems	No accidents
Limited decontamination of selected structures and systems	Decontamination accidents; hazardous materials accidents
Perform general inspections during annual containment entry	No accidents

I.4 References

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I.5 Licensing Basis Documents

One of the sources of information used in this report was licensing basis documents. The sources of information listed below by nuclear facility were consulted. The documents that are listed have been docketed by the NRC and are publicly available. The docket numbers for the facilities are noted below next to the facility name.

The documents can be obtained one of three ways. First, by accessing the NRC's website the reader can obtain most of the Post-Shutdown Defueling Activities Reports (PSDARs) and License Termination Plans (LTPs) that are cited in this chapter. The address for the decommissioning page on the NRC's website is http://www.nrc.gov/OPA/reports/dcmmssng.htm.

Second, the documents can be obtained from the Public Electronic Reading Room, which provides access to the NRC's new records-management system of publicly available information the Agency wide Documents Access and Management System (ADAMS). Within this system you can access two libraries: the Publicly Available Records System, and that Public Legacy Library.

This system, which was implemented on October 12, 1999, marks a change in the previous practice where records were available only in paper or microfiche copies at either the main NRC Public Document Room in Washington, DC or at 86 local public document rooms at libraries near nuclear power plants and other regulated facilities throughout the United States. Access to the NRC Public Electronic Reading Room will now be possible from personal computers, including those located in most public libraries.

ADAMS is an electronic information system that allows access to NRC's publicly available documents via the Internet. It permits full text searching and the ability to view document images, download files, and print locally. It also provides a more timely release of information by the NRC and faster access to documents by the public, than before. The reader can obtain the documents cited in this Appendix by providing the facility name (e.g., Trojan) or the docket number cited for each facility as shown at the end of this section, and the name or date of the document.

ADAMS can be accessed via the Internet at the NRC's website using the following URL: http://www.nrc.gov/NRC/ADAMS/index.html. This site contains instructions for installing and running ADAMS as well as information on obtaining assistance during installation or use.

The Public Electronic Reading Room on the NRC Web site at: www.nrc.gov, allows the public to use the Internet to search for any of the records that NRC has already released to the public. This site uses NRC's Agency wide Documents Access and Management System (ADAMS) to search two electronic libraries: the Public Legacy Library and the Publicly Available Records System (PARS) Library. The Public Legacy Library currently has a selection of bibliographic descriptions and some full text files of NRC records released to the public, prior to Fall 1999. Records in this library were copied from the NRC Bibliographic Retrieval System (BRS) and the Nuclear Document System (NUDOCS), the two systems previously used by the public to search for NRC records. Both BRS and NUDOCS will remain available for searching until all the records are in the Legacy Library. The other library, the Publicly Available Records System (PARS) Library, contains all NRC publicly available records released since Fall 1999. The records in the PARS Library are in, both, full text and image and the public can perform full text searches of the database, as well as view, download, and print the files from there.

Third, the NRC Public Document Room (PDR) at NRC Headquarters in Rockville, Maryland (One White Flint North, 20555 Rockville Pike, Washington DC 20555-0001 (1-800-397-4209), has a complete collection of over two million NRC documents released prior to the Fall of 1999 that are still retained as agency documents. The public may view documents at the PDR and there are reference librarians available to help in identifying, retrieving, organizing, and evaluating NRC documents from various resources and formats, including the Public Electronic Reading Room. Members of the public may also access the Electronic Reading Room libraries from computer terminals in the PDR. The PDR also provides reproduction services and, for a fee, the public can order copies of any of the records in the PDR, the Legacy, and the PARS libraries.

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Appendix J

Socioeconomics and Environmental Justice Impacts Related to the Decision to Permanently Cease Operations

Appendix J

Socioeconomics and Environmental Justice Impacts Related to the Decision to Permanently Cease Operations

This appendix presents information on the socioeconomic and environmental justice aspects of selected nuclear power facilities currently in the decommissioning process or that have recently completed the process. This Appendix provides a discussion of the impacts related to the decision to permanently cease operations that are outside the scope of this Supplement (See Section 1.3). The NRC staff reviewed this information to provide additional information related to concerns raised during scoping and Supplement development about Socioeconomic Impacts (Section 4.3.12) and Environmental Justice (Section 4.3.13).

Impact significance is assigned to specific issues as described in 10 CFR Part 51 Subpart A, Appendix B, Table B-1. The impacts are based on the definitions of three significance levels. Unless the significance level is identified as beneficial, the impact is adverse, or in the case of "small," may be negligible. The definitions of significance follow:

SMALL -- For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

MODERATE -- For the issue, environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE -- For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

J.1 Socioeconomic Impacts

There are two primary pathways through which the decision to permanently cease operations at a nuclear power plant creates socioeconomic impacts on the area surrounding the plant. The first is through direct expenditures in a local community by the plant work force, plus any purchases of goods and services required for plant activities. The second pathway for socioeconomic impact is through the effects on local government tax revenues and services. The impact pathways (direct expenditures and tax revenues) relate specifically to changes in the workforce and population, local tax revenues, housing availability, and public services.

Socioeconomic changes related to direct expenditures in the local community are considered not detectable if there is little or no impact on housing values, education, and other public services, and local government finances are not distinguishable from normal background variation due to other causes. Impacts on housing are considered not detectable when no discernable change in housing availability occurs, changes in rental rates and housing values are similar to those occurring statewide, and little or no housing construction or conversion occurs. Detectable impacts result when there is a discernable increase or reduction in housing availability, rental rates and housing values exceed the inflation rate elsewhere in the State, or more than minor housing conversions and additions or abandonments occur. Destabilizing impacts occur when project-related demand results in a very large excess of housing or very limited housing availability, there are considerable increases or decreases in rental rates and housing values, and there is substantial conversion or abandonment of housing units.

Socioeconomic changes related to tax revenues and services (education, transportation, public safety, social services, public utilities, and tourism and recreation) are considered not detectable if the existing infrastructure (facilities, programs, and staff) could accommodate any changes in demand related to plant closure without a noticeable effect on the level of service. Detectable impacts arise when the changes in demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new local government programs, upgraded or new facilities, or substantial numbers of additional staff and unsupportable levels of resources are required because of facility-related demand.

The information provided here is based, in part, on data obtained from or about facilities that have completed decommissioning and facilities that are currently being decommissioned. This data was obtained in the areas of workforce and population, local tax revenues, housing availability, and public services. The time period used for was the mid-1960s to 2001.

J.1.1 Changes in Work Force and Population

The size of the work force varies considerably among operating U.S. nuclear power facilities, with the onsite staff generally consisting of 600 to 800 personnel per reactor unit. The average permanent staff size at a nuclear power facility site ranges from 800 to 2400 people, depending on the number of operating reactors at the site. In rural or low-population communities, this number of permanent jobs can provide employment for a substantial portion of the local work force. In addition to the work force needed for normal operations, many nonpermanent personnel are required for various tasks that occur during outages. Between 200 and 900 additional workers may be employed during these outages to perform the normal outage maintenance work. These are work force personnel who will be in the local community only a short time, but during these periods of extensive maintenance activities, the additional personnel will have a substantial effect on the locality. If the local economy is stable or declining, the result of the reduction in work force related to plant closure could be economic hardships, including declining property values and business activity, and problems for local government as it adjusts to lower levels of tax revenues.

If there is a net reduction in the community work force but the economy is growing, the adverse impacts of this ongoing growth (e.g., housing shortages and school overcrowding) could be reduced. Changes of over 3 percent to a local population in a single year are expected to have detectable effects, while changes of over 5 percent are expected to result in destabilizing impacts. These negative impacts include reduction of school system enrollments, weakened housing markets, and loss of demand for goods and services provided by local business.

The impact from facility closure depends on the rate and amount of population change. If post-closure work begins shortly after shutdown with a large work force, then the impact of facility closure is mitigated. Facilities where layoffs are sudden and there is a long delay before post-closure work begins are likelier to experience negative population-related socioeconomic impacts. Thus, large plants located in rural areas that permanently shut down early and choose the SAFSTOR option are the likeliest to have negative impacts. Considering all variables such as plant size and community size as the same, plants that go into immediate DECON have fewer negative impacts that are less immediate than those of SAFSTOR. The impacts from the ENTOMB option, assuming those preparations were made immediately after shutdown, would also be less significant than those of SAFSTOR.

In only two cases did the corresponding county populations decline around the time of the closure (Indian Point, Unit 1, in Westchester, New York, and Millstone, Unit 1, in New London, Connecticut). However, during the same time period that the host counties experienced population declines, the hosting States also experienced population declines. This suggests that the decline in the county population was most likely part of an overall State population trend. Observing population trends over a decade may not capture small population declines or reductions in the rate of growth from one year to the next; however, longer trends should indicate whether or not the county had any large destabilizing population or housing impacts from the facility closure.

In 18 out of the 20 facility case studies where populations grew, the populations of the counties where the facilities are located increased more rapidly or at the same rate as the State population. The two cases where the populations of the counties grew at a slower rate include relatively rural counties in California (Humboldt and Alameda) during time periods when California as a whole experienced very high urban population growth.

Data was gathered on the changes in workforce at facilities that are currently being decommissioned (i.e., where operations have ceased), where information on operational and decommissioning workforces was available. This information is shown in Table J-1. The table also shows the total population in the host county at the time of plant shutdown, to indicate the potential importance of the facility closure.

U.S. Census population estimates for the counties that house the closed plants are used to assess population changes around the time of shutdown by comparing percentage changes in county and State populations for the same time periods (Table J-2).

J.1.2 Local Tax Revenues

The tax revenue impacts on the local communities of plant closure vary widely from zero impact (tax-exempt plants) to a loss of 90 percent of the community tax base. The magnitude of tax-related impacts varies primarily by the size of the taxing jurisdiction and the taxing structure of the State in which the plant is sited, as well as certain plant characteristics. All else being equal, the smaller the taxing community (less economically diverse), the greater the tax-revenue impact when the nuclear facility closes down.

In communities where the revenues from the facility made up over 50 percent of the tax revenue base (with the remaining tax revenues made up primarily of private residential real estate), there were significant increases in the tax rates on the remaining real estate as well as cut-backs in services supported by property-tax revenues. The manner in which a State calculates the value of the plant also affects (a) both the amount and timing of tax losses when a nuclear power facility closes and (b) how much such a closure disrupts the tax revenue stream in a given community:

- At one plant, the assessed value of the plant was calculated as a proportional share of the value of the parent corporation, where the percentage is based on the book value of assets in the State (or sub-State taxing jurisdiction) compared with the book value of the assets of the entire corporation. This approach kept the plant at full assessed value for 7 years after its permanent closure until it was dropped from the books of the parent corporation as an asset.

- Tax rules may or may not permit gradual phase-out. In some cases, the taxable asset value of the plants was allowed to phase out over a period of time (3 to 5 years). In other cases, the plants were simply taken off the tax roles in 1 year.

Table J-1. Impact of Plant Closure on Workforce at Nuclear Power Plants Currently Being Decommissioned

Nuclear Plant	Thermal Power	Decommissioning Option[a]	Shutdown Date[b]	Maximum Workforce	Post-termination Workforce	Maximum Workforce Change	County Population
Big Rock Point	240 MW	DECON	08/30/97	--	232	--	24,496 (1997)
Dresden, Unit 1	700 MW	SAFSTOR	10/31/78	--	--	--	--
Fermi, Unit 1	200 MW	SAFSTOR[c]	09/22/72	--	--	--	--
Fort St. Vrain	842 MW	DECON[d]	08/18/89	--	--	--	--
GE-VBWR	50 MW	SAFSTOR	12/09/63	--	--	--	--
Haddam Neck	1825MW	DECON	07/22/96	--	--	--	--
Humboldt Bay, Unit 3	200 MW	SAFSTOR[c]	07/02/76	150	60	90	99,692 (1975)
Indian Point, Unit 1	615 MW	SAFSTOR	10/31/74	--	--	--	--
La Crosse	165 MW	SAFSTOR	04/30/87	82	23	59	25,965 (1987)
Maine Yankee	2700 MW	DECON	12/06/96	481	360	121	31,760 (1997)
Millstone, Unit 1	2011 MW	SAFSTOR	11/04/95	--	--	--	--
Pathfinder	190 MW	SAFSTOR[d]	09/16/67	--	--	--	--
Peach Bottom, Unit 1	115 MW	SAFSTOR	10/31/74	--	--	--	--
Rancho Seco	2772 MW	SAFSTOR[c]	06/07/89	--	200-250	--	--
San Onofre, Unit 1	1347 MW	SAFSTOR[c]	11/30/92	424	295	129	2,723,782 (1997)
Saxton	23 MW	SAFSTOR[c]	05/01/72	--	--	--	—
Shoreham	2436 MW	DECON[d]	06/28/89	–	–	—	1,303,501 (1989)
Three Mile Island, Unit 2	2772 MW	Accident cleanup, followed by storage	03/28/79	1150	125	1125	222,100 (1979)
Trojan	3411 MW	DECON	11/09/92	1319	177-432	887-1142	44,513 (1997)
Yankee Rowe	600 MW	DECON	10/01/91	--	--	--	--
Zion, Unit 1	3250 MW	SAFSTOR	02/21/97	--	--	--	--
Zion, Unit 2	3250 MW	SAFSTOR	09/19/96	--	--	--	—

(a) The option shown in the table for each plant is the option that has been officially provided to NRC. Plants in DECON may have had a short (1 to 4 yr) SAFSTOR period. Likewise, plants in SAFSTOR may have performed some DECON activities or may have transitioned from the storage phase into the decontamination and dismantlement phase of SAFSTOR.
(b) The shutdown date corresponds to the date of the last criticality.
(c) Plant has recently performed or is currently performing the decontamination and dismantlement phase of SAFSTOR.
(d) Plants has completed decommissioning

Table J-2. County and State Population Changes During Plant Closure and Decommissioning

Nuclear Plant	Reactor Type	Thermal Power	Decommissioning Option	Location	County	County Population	County Population Change, %	State Pop. Change, %
Big Rock Point	BWR	240 MW	DECON	Charlevoix, MI	Charlevoix	24,496 (1997)	6.5	1.7
Dresden, Unit 1	BWR	700 MW	SAFSTOR	Morris, IL	Grundy	28,400 (1975)	14.9	2.8
Fermi, Unit 1	FBR	200 MW	SAFSTOR	Monroe Co., MI	Monroe	126,300 (1975)	12.7	4.1
Fort St. Vrain	HTGR	842 MW	DECON	Platteville, CO	Weld	130,764 (1979)	18	18
GE-VBWR	BWR	50 MW	SAFSTOR	Alameda Co., CA	Alameda	1,071,446 (1975)	2.6	16.4
Haddam Neck	PWR	1825 MW	DECON	Haddam, CT	Middlesex	149,010 (1997)	4.1	4.2
Humboldt Bay, Unit 3	BWR	200 MW	SAFSTOR	Eureka, CA	Humboldt	99,692 (1975)	9.8	25.8
Indian Point, Unit 1	PWR	615 MW	SAFSTOR	Buchanan, NY	Westchester	874,300 (1975)	-2.7	-3.3
La Crosse	BWR	165 MW	SAFSTOR	Genoa, WI	Vernon	25,965 (1987)	6.1	5.7
Maine Yankee	PWR	2700 MW	DECON	Wiscasset, ME	Lincoln	31,760 (1997)	5.8	2.6
Millstone, Unit 1	BWR	2011 MW	SAFSTOR	Waterford, CT	New London	246,959 (1997)	-0.8	-0.5
Pathfinder	BWR	190 MW	SAFSTOR	Sioux Falls, SD	Minnehaha	95,209 (1975)	12.2	3.4
Peach Bottom, Unit 1	HTGR	115 MW	SAFSTOR	Delta, PA	York	272,603 (1975)	13.8	1
Rancho Seco	PWR	2772 MW	SAFSTOR	Sacramento, CA	Sacramento	869,581 (1989)	8.1	8.3
San Onofre, Unit 1	PWR	1347 MW	SAFSTOR	San Clemente, CA	San Diego	2,723,782 (1997)	9	8.3
Saxton	PWR	23 MW	SAFSTOR	Saxton, PA	Bedford	42,353 (1975)	10.7	1
Shoreham	BWR	2436 MW	DECON	Suffolk County, NY	Suffolk	1,303,501 (1989)	3.1	0.5
Three Mile Island, Unit 2	PWR	2772 MW	Accident cleanup, followed by storage	Middletown, PA	Dauphin	232,317 (1979)	2.4	0.2
Trojan	PWR	3411 MW	DECON	Rainier, OR	Columbia	44,513 (1997)	16.5	14.1
Yankee Rowe	PWR	600 MW	DECON	Rowe, MA	Franklin	70,626 (1997)	1.8	1.7
Zion, Unit 1	PWR	3250 MW	SAFSTOR	Zion, IL	Lake	594,799 (1997)	8.3	4.4
Zion, Unit 2	PWR	3250 MW	SAFSTOR	Zion, IL	Lake	594,799 (1997)	8.3	4.4

- The State may or may not share the burden with local government. In one State, school districts' lost property-tax collections were offset by equalization methods at the State level, which reduced the impact due to plant closures. In another State, the small neighboring township was the sole recipient of all property-tax revenues generated by the plant. Thus, the community's tax revenues were significantly reduced when the revenue source shut down.

- In addition, ratepayers in some jurisdictions are entitled to share in funds recovered from the sale of plant components and commodities and unspent decommissioning funds. These are not taxes but are available to general fund revenues.

In addition to characteristics specific to the taxing jurisdiction, the size, age, and ownership of the facilities play a role in how much the facilities affect tax revenues. Generally, the larger the facility (in the MWt), the larger the tax revenue impact. In addition, aging of the facilities depreciates its book value and assessed value over time. Usually, the falling assessed value of an aging facility will have reduced the tax revenue of the facility before closure, thus lessening the change in tax revenues generated by the facility after closure. A facility that closes suddenly, well before the end of its license expiration, will have a greater impact on the community tax base. Finally, if a facility is owned by a public entity, there is no effect on the tax base from closure because the facility was never taxable.

Changes in tax revenues of less than 10 percent are considered not detectable, i.e., they resulted in little or no change in local property tax rates and the provision of public services. Losses between 10 percent and 20 percent result in detectable impacts, with increased property tax levies (where State statutes permit) and decreased services by local municipalities. Changes over 20 percent have destabilizing impacts on the governments involved. Tax levies must usually be increased substantially or services cut substantially, and the payment of debt for any substantial infrastructure improvements made in the past becomes extremely problematic. Borrowing costs for local jurisdictions may also increase because bond rate agencies downgrade their credit rating. However, it is important to remember that these rules of thumb are based on uncompensated changes. For example, if a local taxing jurisdiction lost a nuclear facility that amounted to 35 percent of its tax base, but 30 percentage points of this loss were made up by the opening of a new manufacturing facility, the net impact would be 5 percent or not detectable. Small, rural areas are more likely to be affected than more urban areas having a wider variety of economic opportunities and more sources of tax revenue. Impacts depend on the type of plant, size of plant, and whether or not there are multiple units at a site, all of which help determine the net loss in employment at plant closure as well as the loss of tax base.

Table J-3 shows the impact of closure on local tax revenues for selected plants currently in decommissioning (or that have completed decommissioning), for which data are available. The primary taxing authorities for most of the closed plants are the county and city in which the plant is sited. Tax information is typically provided by local taxing authorities (an assessor's office) or from town planners familiar with the tax revenues generated by the plants. Only in the case of Humboldt Bay was tax-impact information available on a smaller, older plant (-$377,000 in 1983-84). The plants where information is not available are very small plants that most likely had very little impact on the tax base of the community. Many of these plants were shut down in the 1960s and 1970s.

Table J-3. Impact of Plant Closure on Local Tax Revenues

Nuclear Plant	Location	Shutdown Date	Thermal Power	Decom-missioning Option	Tax Revenues Change, millions (M)	Tax Change, %	Notes
Big Rock Point	Charlevoix, MI	08/30/97	240 MW	DECON	--	--	--
Haddam Neck	Middlesex, CT	07/22/96	1825 MW	DECON	yr 1 -$0 7M yr 2 -$0.7M yr 3 -$1.3M yr 4 -$1.2M yr 5 -$0 5M	-30% (phased out over 5 yr)	
Maine Yankee	Wiscassset, ME	12/06/96	2700 MW	DECON	yr 1 -$6 3M yr 2 -$2 5M yr 3 -$1.1M yr 4 -$0 6M	-70% (phased out in 4 yr)	Taxes paid to town. Plant made up about 90% of tax revenue. They have phased out tax expenditure payments over 6-yr period
Millstone, Unit 1	Waterford, CT	11/04/95	2011 MW	SAFSTOR	-$0 8M	-2% due to plant closure	Impacts to tax revenues in this area during this time include 1) the natural depreciation rate of Unit 1. Assessment had become less than 5% of market value of plant by time of closure (2) Deregulation environment brings assessed value of plants down 50%
Rancho Seco	Sacramento, CA	6/7/89	2772 MW	SAFSTOR	no change	0	Rancho Seco was tax-exempt because it is considered to be owned by the government. Besides sales tax, etc., no impact.
San Onofre, Unit 1	San Clemente, CA	11/30/92	1347 MW	SAFSTOR	yr 1 -$1 2M yr 2 -$1.1M yr 3 -$1.2M		
Shoreham	Suffolk Co , NY	06/28/89	2436 MW	DECON	-$10M/yr up to -$115M total change after phase-out	10% decrease in yr 1, to 60% decrease by 2003	This county was hit hard by the abrupt manner in which this plant ceased operation and the lawsuits over tax assessment that proceeded (in which a judge determines assessed value close to 0 based on projected income stream from plant).
Three Mile Island, Unit 2	Middletown, PA	03/28/79	2772 MW	Accident cleanup followed by storage	no change	0	Utilities were tax exempt in 1979.
Trojan	Rainier, OR	11/09/92	3411 MW	DECON	yr 1-7 no change yr 8 -$2 3M	7.3% reduction for the county as a whole Loss of 52 6% for one rural fire protection district.	Oregon taxes on the basis of the percentage of capital value of the parent company (ENRON) in county, based on 87% of book value of the parent in state. The Trojan "asset" stayed on ENRON's books until the year 2000.
Yankee Rowe	Rowe, MA	10/01/91	600 MW	DECON	-$0 4M	12% reduction	Rowe has a hydro-electric plant that generates most of the tax revenue (over 75%) This alleviated some of the tax impacts
Zion, Units 1 and 2	Zion, IL	02/21/97 and 09/19/96	3250 MW (each)	SAFSTOR	yr 1 -$0 4M yr 2 -$3M yr 3 -$7M	12% in yr 1, rising to 50% by yr 5 (2002)	This is an assessment of both units together. There is a phase- out approach, where assessed value is reduced from $210 M to $10 M over 8 yr

J.1.3 Housing Availability

The prevailing belief of realtors and planners in communities surrounding the case study facilities is that closing the facilities has had a range of effects on the marketability or value of homes in the vicinity. Housing choices of local residents are rarely affected by the presence of the facility, but people may move into the area in response to (temporarily) softer housing prices and commute to a nearby urban area.

J.1.4 Public Services

The impacts of closure on public services are closely related to the tax-related impacts on the community and are affected by the same characteristics of the plant: its size and age, its tax treatment, and the dependence of the local community on plant-related revenues, but not on the choice of decommissioning option or the amount of time between shutdown and active decommissioning. The impacts to the following public services may occur as a result of plant closure: education, transportation, public safety, social services, public utilities, and tourism and recreation.

Inquiries were made to local governments in the vicinity of closed plants about public service impacts during and after shutdown and decommissioning (Table J-4). Analysis was also conducted in the course of preparing NUREG-1437 (NRC 1996). Based on that experience, the following generalizations can be made.

In general, detectable impacts arise when the demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new programs, upgraded or new facilities, or substantial additional resources and staff are required because of facility-related demand.

In general, the communities that suffered the most from the tax-related impacts of plant closure also experienced the greatest impacts on public services. To some extent, the communities themselves control the amount of impact by how they allocate property taxes to local budgets before shutdown and how they prioritize these services post-shutdown. For example, one community channeled a great deal of the surplus revenues into building extensive social services for the elderly and for local youth in its community. After the plant ceased operations, the tax revenues decreased, all of the social services were downsized, and many will be eliminated because these are not considered to be priority programs (relative to public safety and education). In a second case, the county provided relatively few social services. Thus, the impact on social services after the shutdown was minor, although several other categories of

Table J-4. Impact of Plant Closure on Local Public Services

Nuclear Plant	Housing	Education	Transportation	Public Safety	Social Services	Public Utilities	Tourism and Recreation
Big Rock Point	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Dresden, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Fermi, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Fort St. Vrain	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
GE-VBWR	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Haddam Neck	SMALL to MODERATE	MODERATE	SMALL to MODERATE	MODERATE	SMALL to MODERATE	SMALL	SMALL
Humboldt Bay, Unit 3	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Indian Point, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
La Crosse	SMALL	SMALL to MODERATE	SMALL	SMALL to MODERATE	SMALL	SMALL	SMALL
Maine Yankee	MODERATE	MODERATE	SMALL	MODERATE	SMALL	SMALL	SMALL
Millstone, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Pathfinder	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Peach Bottom, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Rancho Seco	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
San Onofre, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Saxton	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Shoreham	MODERATE	MODERATE to LARGE	MODERATE	MODERATE	SMALL to MODERATE	MODERATE	SMALL
Three Mile Island, Unit 2	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Trojan	SMALL to MODERATE	MODERATE	SMALL	SMALL to MODERATE	SMALL	SMALL	SMALL
Yankee Rowe	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Zion, Unit 1	SMALL	MODERATE	MODERATE	MODERATE	MODERATE to LARGE	SMALL	SMALL
Zion, Unit 2	SMALL	MODERATE	MODERATE	MODERATE	MODERATE to LARGE	SMALL	SMALL

public service experienced larger impacts. For example, education was largely funded by plant tax revenues and the responsible school district has recently indicated that it may have to file for bankruptcy, so the impact there was substantial.[a]

(a) The size of impact can be significantly influenced by the mechanism that the State uses for funding, e.g., if the State makes up the difference between what the local school districts can fund from the local property tax and what the State has decided is the appropriate level of per-student expenditures.

In general, impacts are nondetectable and nondestabilizing if the existing infrastructure (facilities, programs, and staff) could accommodate any plant-related demand without a noticeable effect on the level of service. Detectable and nondestabilizing impacts arise when the demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Detectable and destabilizing impacts would result when new programs, upgraded or new facilities, or substantial additional staff are required because of plant-related demand. The impacts of plant closure were determined for education, transportation, public safety, social services, public utilities, and tourism and recreation.

Education: The NRC considered changes in enrollment in another licensing framework (see *The Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. In general, nondetectable and nondestabilizing impacts are associated with project-related enrollment increases of 3 percent or less. Impacts are considered nondetectable and nondestabilizing if there is no change in the school systems' abilities to provide educational services and if no changes in the number of teaching staff or classroom space are needed. Detectable but destabilizing impacts generally are associated with 4 to 8 percent decreases in enrollment. Impacts are considered moderate if a school system must decrease its teaching staff or classroom space even slightly to preserve its pre-project level of service. Any decrease in teaching staff, however small (e.g., 0.5 full-time equivalent), that occurs from retiring or laying off personnel or changing the duties of existing personnel (e.g., a guidance counselor assuming classroom duties) may result in moderate impacts, particularly in small school systems. Detectable and destabilizing impacts are associated with project-related enrollment decreases of more than 8 percent. Some of the case-study communities had challenges adjusting to the loss of children of the plant staff from the local school systems. For example, some of the local schools had to go on a 4-day week in the Rainier, Oregon, area because loss of enrollment made the schools much more expensive to run per student served.

Transportation: The U.S. Nuclear Regulatory Commission (NRC) considered transportation issues in another licensing framework (see NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. That framework considered impacts on the Transportation Research Board's level of service (LOS) definitions (Transportation Research Board 1985). LOS is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists.

LOS A and B are associated with nondetectable and nondestabilizing impacts because the operation of individual users is not substantially affected by the presence of other users. At this level, no delays occur and no improvements are needed. LOS C and D are associated with detectable and nondestabilizing impacts because the operation of individual users begins to be severely restricted by other users, and at level D small increases in traffic cause operational problems. Consequently, upgrading of roads or additional control systems may be required. LOS E and F are associated with detectable and destabilizing impacts because the use of the roadway is at or above capacity level, causing breakdowns in flow that result in long traffic delays and a potential increase in accident rates. Major renovations of existing roads or additional roads may be needed to accommodate the traffic flow.

Impacts to transportation during the license renewal term would be similar to or less than those experienced during current operations, driven mainly by the workers involved in plant closure, who are generally fewer in number than the operating staff. Consequently, LOS conditions are likely to move in the direction of A and B at all plants. Based on past and projected impacts at the case study sites, transportation impacts would continue to be nondetectable and nondestabilizing at all sites.

Public safety: Impacts on public safety are considered nondetectable and nondestabilizing if there is little or no need for additional police or fire personnel. No disruptions of police and fire-protection services occurred at the case-study sites after plant closure. Existing services were adequate to handle the influx of decommissioning staff, who are less numerous than the operations staff.

Social services: The impacts on social services are considered nondetectable and nondestabilizing if no change in the current level of service occurs, detectable and nondestabilizing if service declines noticeably, and detectable and destabilizing if services are seriously disrupted. Impacts on social services following closure largely depend on the ability of the community to replace the jobs lost at the end of operations or to successfully assist the laid-off workers and other affected workers in the community to transition out of the community. Most of the case-study sites have been able to do this, so closure impacts have been nondetectable and nondestabilizing to detectable but nondestablizing.

Public utilities: The NRC considered public utility issues in another licensing framework (see NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. As in that framework, impacts on public-utility services are considered nondetectable and nondestabilizing if little or no change occurs in the ability to respond to the level of demand, and, thus, there is no need to add to capital facilities. Impacts are considered detectable and nondestabilizing if overtaxing of facilities during peak demand periods occurs. Impacts are considered detectable and destabilizing if existing service levels (such as the quality of water and sewage treatment) are substantially degraded and additional capacity is needed to meet ongoing demands for services. Overall, there have been nondetectable and nondestabilizing impacts on public utilities as a result of plant closure. The existing capacity of public utilities was sufficient to accommodate the small influx of decommissioning staff, and some locales experienced a noticeable decrease in the level of demand for services with the completion of plant operations.

Tourism and recreation: Few adverse effects have occurred during current operations at the case-study sites, and some positive effects have resulted because taxes paid by the plants and tours of the plants have also increased local tourism. Based on the case-study analysis, it is projected that because decommissioning essentially turns the operating facility back into a construction site while removing tax payments, the impacts of plant closure should be temporary, nondetectable and nondestabilizing at all plants. Some positive impact to tourism and recreation also may continue if the plant site is then converted for tourism activities, as planned for Trojan.

J.2 Environmental Justice

An evaluation of environmental justice is performed to determine if minority and low-income groups bear a disproportionate share of negative environmental consequences. Selected socioeconomic indicators are found in Table J-5 for closed nuclear power plants for which data were available. These include the median county family income as a percentage of State median family income in the year 1989, and the percentage of minority (non-white plus white Hispanic) persons in the county in the year 2000.

J.3 Reference

U. S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

Table J-5. Socioeconomic Indicators Relevant to Environmental Justice at Closed Nuclear Power Plants

Nuclear Plant	Reactor Type	Decommissioning Option	Public Services Impacts	County Median Family Income (MFI), as % of State MFI[a]	Minority (Non-White and White Hispanic) in County, %[b]
Big Rock Point	BWR	DECON	SMALL	79.5	< 5
Dresden, Unit 1	BWR	SAFSTOR	SMALL	107.4	< 6
Fermi, Unit 1	FBR	SAFSTOR	SMALL	110.4	< 6
Fort St. Vrain	HTGR	DECON	SMALL	85 8	30
GE-VBWR	BWR	SAFSTOR	SMALL	110 9	59
Haddam Neck	PWR	DECON	SMALL to MODERATE	103.4	10
Humboldt Bay, Unit 3	BWR	SAFSTOR	SMALL	74 8	18
Indian Point, Unit 1	PWR	SAFSTOR	SMALL	148.3	35
La Crosse	BWR	SAFSTOR	SMALL	75.4	< 2
Maine Yankee	PWR	DECON	SMALL to MODERATE	103.1	< 2
Millstone, Unit 1	BWR	SAFSTOR	SMALL	87.9	15
Pathfinder	BWR	SAFSTOR	SMALL	124.2	< 8
Peach Bottom, Unit 1	HTGR	SAFSTOR	SMALL	107.7	< 9
Rancho Seco	PWR	SAFSTOR	SMALL	93.2	42
San Onofre, Unit 1	PWR	SAFSTOR	SMALL	128.3	45
Saxton	PWR	SAFTSOR	SMALL	72.7	< 2
Shoreham	BWR	DECON	SMALL to MODERATE	134 0	21
Three Mile Island, Unit 2	PWR	Accident cleanup, followed by storage	SMALL	106.9	24
Trojan	PWR	DECON	SMALL to MODERATE	106 5	< 7
Yankee Rowe	PWR	DECON	SMALL	82 4	< 6
Zion, Unit 1	PWR	SAFSTOR	MODERATE	135.2	26
Zion, Unit 2	PWR	SAFSTOR	MODERATE	135 2	26

(a) Source: 1990 Census of Population. *American Factfinder* Table 1990 QT. http://factfinder.census.gov
(b) Source: 2000 Census of Population. *American Factfinder* Table QT. http //factfinder census.gov

Appendix K

Transportation Impacts

Appendix K

Transportation Impacts

A generic analysis was conducted to estimate human health impacts associated with transporting decontamination and dismantlement wastes from reactor sites to low-level waste (LLW) burial grounds using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992). RADTRAN was originally developed by Sandia National Laboratory to support the NUREG-0170 (NRC 1977) environment impact analysis and is commonly used for transportation impact calculations in support of environmental documentation. The more recent code, RADTRAN 5 (Neuhauser and Kanipe 1996), which uses the RADTRAN 4 models in stochastic framework, was not used because the goal of the analysis was to estimate bounds of impacts rather than a probabilistic distribution of impacts. The results of the RADTRAN 4 analysis are found in Section 4.3.17. The following is a discussion of the model input parameters.

- Waste volumes: The total volume of LLW generated during reactor decontamination and dismantlement is a function of the alternative being implemented. Waste volume estimates for decommissioning facilities were obtained for eight facilities from Post Shutdown Decommissioning Activity Reports (PSDARs), Environmental Reports (ERs), or data provided by licensees with the assistance of the Nuclear Energy Institute (NEI). Because of the small number of facilities from which estimates were obtained, the data tends to be skewed by the unique attributes of the decommissioning process for a given plant. For example, the only pressurized water reactor (PWR) facility with data for the SAFSTOR option is San Onofre, a plant that is removing all structures. The information received on LLW is summarized in Table K-1. The actual number of shipments of waste from a site during decommissioning may be inflated by State and local government regulations that require removal of all structures and concrete from the site, whether contaminated or not. For a number of sites listed in Table K-1, all waste was considered LLW, which inflated the values in the table.

  The Trojan Nuclear Plant Radiological Site Characterization Report (Trojan 1995) and the Maine Yankee License termination plan (Maine Yankee 2001) clearly show that all low-level waste is not the same. There is a relatively small volume of waste that includes the reactor vessel and internal components that has most of the residual radioactivity following cessation of operations (about 2.5-million curies). There is a slightly smaller volume of waste, such as concrete containing activation products, that contains most of the remaining residual activity (several hundred curies), and a much larger volume of waste that contains

Table K-1. Low-Level Waste Shipment Data for Decommissioning Nuclear Power Facilities

Nuclear Plant	Reactor Type	Decommissioning Option	LLW Volume, cubic meters	LLW Shipments	Distance, km (mi)
Maine Yankee	PWR	DECON	31,924 plus 853[b]	364 (truck), 181 (rail), 2 (barge)[b]	1900-4600 (1200-2860)
Haddam Neck	PWR	DECON	8017	496-582	1500-4000 (1400-2500)
Trojan	PWR	DECON	9765	470	482 (300)
San Onofre, Unit 1	PWR	SAFSTOR	--	91 (truck) 869 (rail)	--
Saxton	PWR	SAFSTOR	580	100	1000 (620)
Rancho Seco	PWR	SAFSTOR		1250 (truck) <25 (rail)	1000-4300 (620-2700)
Big Rock Point	BWR	DECON	2042	--	--
Millstone, Unit 1	BWR	SAFSTOR	18,014	--	--
Yankee Rowe[a]	PWR	DECON	4136	--	--

(a) From NUREG-1307, Rev. 9, p. A.3.
(b) Reactor pressure vessel and steam generators.

small amounts of activity (a few curies). The breakdown of LLW assumed for the evaluation of impacts of LLW transportation is shown in Table K-2.

- Number of shipments: The number of shipments was also determined from PSDARs, ERs, and data provided by NEI. These numbers represent the total number of shipments over the entire decommissioning period, which mostly occurs during decontamination and dismantlement and takes place in a period of 2-6 years. Shipment estimates were obtained for six facilities. The estimates vary significantly based on mode of transportation available at the site (truck, rail or barge), the decommissioning option chosen, the decommissioning methods being employed, the extent of facility dismantlement, and state and local requirements.

  Table K-2 includes the number of shipments estimated for each type of LLW in this analysis. The estimates were derived from the volume estimates by assuming that, on the average, each shipment of high-activity waste moved 5.3 m^3 (6.9 cubic yards) of material (capacity of a CNS 14-190 shipping cask), and each shipment of low-activity and very low-activity waste .

Table K-2. Volume and Activity Assumed for Evaluation of Radiological Impacts of Transportation of Low-Level Waste

	Total Volume, m^3 (ft^3)	Total Activity, Bq (Ci)	Activity Density, Bq/m^3 (Ci/m^3)	Shipments
High-activity waste (reactor vessel and internal components)	1200 (42,400)	9.81×10^{16} (2,650,000)	8.14×10^{13} (2200)	227
Low-activity waste (activated concrete)	750 (26,500)	1.5×10^{13} (400)	1.97×10^{10} (0.533)	84
Very low-activity waste (debris, soil)	5400 (191,00)	3.7×10^{11} (10)	6.85×10^{7} (0.0019)	360

moved 9 m^3 (12 cubic yards) of material (equivalent to 48 55-gal. drums). The reduced volume of material per shipment of the high activity waste reflects the shielding required to keep dose rates and truck weight within legal limits.

- Shipping distance: Transportation impacts and costs are a function of the distance traveled. Distances for decommissioning facilities range from 8 km (5 mi) to 4540 km (2840 mi). A bounding shipping distance of 4800 km (3000 mi) one-way was assumed for evaluation of radiological impacts of transportation; a round trip distance of 9600 km (6000 mi) was assumed for nonradiological impacts.

- Land class information: RADTRAN permits division of the transportation route into urban, suburban, and rural segments. Input to the code includes the fraction of the route that falls into each of these land-use classes, the population density in each segment, and the transport speed in each segment. Table K-3 gives the values for RADTRAN parameters used in the evaluation of LLW transport that are functions of land-use class. The percentage of the route and population density for each land-use class was estimated from routes for transport from the northeast and southeast United States to Nevada (Ramsdell et al. 2001), and the transport speeds were taken from NUREG/CR-6672 (Sprung et al. 2000). Accident rates given by Saricks and Tompkins (1999) were used in the calculations. They give the national average fatality rate for trucks as 5.5×10^{-9} fatalities per kilometer (8.8×10^{-9} fatalities per mile).

- Radiation dose rate: In calculating the doses to the public (onlookers and along the route), the radiation dose rate emitted from the shipping container was assumed to be at

Table K-3. RADTRAN Land-Use Class Dependent Parameter Values Assumed for Evaluation of Impacts of Transportation of LLW

Land-Use	Percent of Route	Population Density, people/km^2 (people/mi^2)	Transport Speed, km/h (mi/h)	Accidents per km (mi)
Urban	3	7.7 (20)	88 (55)	3.15×10^{-7} (5.07×10^{-7})
Suburban	18	390 (1000)	88 (55)	3.66×10^{-7} (5.89×10^{-7})
Rural	79	2300 (6000)	88 (55)	6.54×10^{-7} (1.05×10^{-7})

the regulatory maximum limit for transportation of high-activity waste and one-tenth of the regulatory limit for transportation of low-activity waste. The activity estimates for very low-activity waste are sufficiently small that the activity may be neglected in the evaluation of the radiological impacts of transportation of LLW. Dose rates for workers were calculated assuming 2.0×10^{-5} Sv/h (2 mrem/h).

- Radioactive material inventory: The inventory of radioactive material in a given shipment is variable. For the high-activity waste, which includes reactor vessel and internal components, the dominant radionuclides are activation products of the constituents of steel. Similarly, the dominant radionuclides in the low-activity waste are activation products of the constituents of concrete, with lesser contributions from surface contamination. Radionuclide distributions reported for residual radiation at Trojan (Trojan 1995) and Maine Yankee (Maine Yankee 2001) form the basis for the activity assumed in evaluation of the radiological impacts of LLW transport, which is shown in Table K-4. The specific isotopes for each type of LLW were selected by considering the fraction of the total activity represented by each isotope combined with the radiological consequences of exposure to the isotope. The total activity and radionuclide distributions given in these reports are generally consistent with activity and distribution estimates given in early estimates for reference reactors (Smith et al. 1978; Oak et al. 1980). RADTRAN 4 does not include nickel-63 in its library, so it was not included in the dose calculations for accidents. However, the dose is dominated by the contribution of cobalt-60 such that the dose from nickel-63 would have been negligible had it been included.

The transportation of the very low-activity waste is considered in evaluation of the nonradiological impacts of LLW transportation. In fact, most of the nonradiological impacts of transporting LLW are the result of transporting the very low-level activity because these impacts are directly associated with the number of miles driven but not with the amount of activity moved.

- Material Characterization: RADTRAN offers several default options for characterization of the dispersability of material for purposes of evaluation of the radiological consequences of transportation accidents. For this analysis, the high-activity waste was characterized as immobile because the material being transported is primarily composed of metal and the activity is primarily activation products in the metal. In an accident, 0.0001 percent of the immobile material is assumed to become airborne, and 5 percent of the airborne material is assumed to be respirable. Similarly, the low-activity waste was characterized as "loose chunks" because it tends to be concrete pieces with activation products dominating the activity. In an accident, 1 percent of the material in loose chunks is assumed to become airborne, and 5 percent of the airborne material is assumed to be respirable. These fractions, which are the RADTRAN default values, are adapted from NUREG-0170 (NRC 1977).

Table K-4. Low-Level Waste Activity Distributions Assumed for Evaluation of Radiological Impacts of LLW

	Activity Fraction		Activity per Truckload, Bq (Ci)	
	High-Activity Waste	**Low-Activity Waste**	**High-Activity Waste**	**Low-Activity Waste**
Mn-54	0.001	--	5.2×10^{11} (14)	--
Fe-55	0.348	--	1.5×10^{14} (4070)	--
Co-60	0.573	0.269	2.5×10^{14} (6680)	8.0×10^{10} (1.29)
Ni-63	0.078	--	3.4×10^{13} (920)	--
Cs-134	--	0.020	--	3.7×10^{9} (0.10)
Cs-137	--	0.010	--	1.9×10^{9} (0.05)
Eu-152	--	0.652	--	1.1×10^{11} (3.08)
Eu-154	--	0.059	--	1.0×10^{10} (0.28)

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K.2 Related Documents

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Connecticut Yankee Atomic Power Company, Letter CY-97-075. August 22, 1997. Letter from T.C. Feigenbaum to U.S. Nuclear Regulatory Commission. "Haddam Neck Plant-Post Shutdown Decommissioning Activities Report."

Consumers Energy Company, License DPR-6. September 19, 1997. Letter from Kenneth P. Powers to U.S. Nuclear Regulatory Commission. "Big Rock Point Plant-Post Shutdown Decommissioning Activities Report; Revision 2."

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Appendix L

Relevant Regulations and Federal Permits

Appendix L

Relevant Regulations and Federal Permits

This appendix highlights the U. S. Nuclear Regulatory Commission's (NRC's) regulations and Federal statutes and regulations enacted by other Federal agencies as well as Executive Orders that are applicable to decommissioning nuclear power plants.

L.1 Applicable NRC Regulations

A brief summary of the applicable regulations of Title 10 CFR related to decommissioning are provided in this subsection. Although not a comprehensive list, this appendix briefly discusses those regulations that are most pertinent to decommissioning and were considered to be potentially of greatest interest to the reader. Licensees of facilities being decommissioned are required to continue following the regulations applicable to an operating plant unless directed otherwise by the regulations.

L.1.1 10 CFR Part 20, Standards for Protection Against Radiation

Sections of 10 CFR Part 20 establish the NRC regulations pertaining to radiological protection.

Subpart B - Radiation Protection Programs

Subpart B of 10 CFR Part 20 provides the framework for the radiation protection programs required at licensed facilities. It requires that each licensee develop and implement a radiation protection program, that the concept of keeping doses as low as reasonably achievable (ALARA) be an integral part of the program, and that the licensee annually review the program to ensure compliance with all regulations. The need for an adequate radiation protection program is essential for decommissioning plants to ensure the health and welfare of the licensee's personnel and the public.

Subpart C - Occupational Dose Limits

Subpart C of 10 CFR Part 20 provides the radiological occupational dose limits for licensee personnel and the public and the method used to demonstrate compliance with these limits.

Subpart D - Radiation Dose Limits for Individual Members of the Public

Subpart D of 10 CFR Part 20 contains the regulations that define the maximum dose limits that an individual member of the public may receive and acceptable compliance methods. These regulations are applicable for operating and decommissioning plants until license termination. Appendix B provides reference material used for determining annual limits on intake and derived air concentrations of radionuclides for occupational exposure and effluent and sewage release concentrations.

Subpart E - Radiological Criteria for License Termination

Subpart E of 10 CFR Part 20 contains the radiological criteria for license termination that apply to unrestricted and restricted use. Important aspects of the criteria include the opportunity for public participation and the assurance of adequate decommissioning funds to ensure sufficient oversight to protect public health.

Subpart F - Surveys and Monitoring

Subpart F of 10 CFR Part 20 requires surveys and monitoring commensurate with the conditions at a licensed facility. Until the license is terminated at a facility, there is a potential for radiological exposure, which would necessitate continued radiological monitoring and surveys.

Subpart G - Control of Exposure from External Sources in Restricted Areas

Subpart G of 10 CFR Part 20 requires the licensee to control access to high and very high radiation areas. These regulations are applicable to a decommissioning plant, especially in the early years of decommissioning.

Subpart H - Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas

Subpart H of 10 CFR Part 20 requires measures to control airborne radioactive materials and the use of protective equipment to limit personnel intake.

Subpart I - Storage and Control of Licensed Material

Subpart I of 10 CFR Part 20 addresses the security and control issues related to licensed material (source material or by-product material that includes highly irradiated materials).

Subpart J - Precautionary Procedures

Subpart J of 10 CFR Part 20 defines radiological posting requirements to indicate where radiation areas are located and to label containers of licensed materials. The minimum quantities that require labeling are provided in Appendix C of 10 CFR Part 20.

Subpart K - Waste Disposal

Subpart K of 10 CFR Part 20 provides the requirements for the disposal of licensed material, including low-level waste. It provides the regulations related to manifests and manifest tracking.

Subpart L - Records

Subpart L of 10 CFR Part 20 provides requirements for recordkeeping of radiological control records. This includes individual exposure records, historical recordkeeping, and any release of radioactive effluents to the environment. Audit rectors and other reviews of the radiological control program content and implementation are required to be maintained for a period of 3 yrs, which could conceivably extend beyond the decommissioning process.

Subpart M - Reports

Subpart M of 10 CFR Part 20 provides the regulations pertaining to reporting requirements at licensed facilities. The reporting requirements contained in this subpart pertain to theft or loss of licensed materials, incident notification, radiological exposures that exceed limits, special exposures, individual overexposure, and individual monitoring. Annual personnel monitoring reports on personnel exposure are also required to be submitted.

L.1.2 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities

10 CFR 50.82, Termination of License

The current rule for decommissioning was published in August 1996 providing major changes from the previous rule. The current rule redefines the decommissioning process and requires licensees to provide the NRC with early notification of planned decommissioning activities. The rule describes the following:

- information on certifications of permanent cessation of operation and permanent removal of fuel from the plant [10 CFR 50.82(a)(1)(i), and (ii)]

- the submittal of the post-shutdown decommissioning activities report (PSDAR) (10 CFR 50.82(a)(4)(i)), which discusses the decommissioning activities and schedule for the activities, an estimate of expected costs, and the reasons for concluding that the environmental impacts associated with the site-specific decommissioning activities will be bounded by previously described environmental impacts [10 CFR 50.82(a)(4)(i)]

- the restrictions of activities of licensees performing decommissioning activities that may (a) foreclose release of the site for possible unrestricted use, (b) result in significant environmental impacts not previously reviewed, or (c) result in there no longer being reasonable assurance that adequate funds will be available for decommissioning [10 CFR 50.82(a)(6)]

- the requirement for the licensee to notify the NRC before performing any decommissioning activity inconsistent with, or making any significant schedule change from, those activities and schedules described in the PSDAR [10 CFR 50.82(a)(7)]

- how the decommissioning trust funds can be used - Withdrawals from the decommissioning trust fund can only be used [10 CFR 50.82(a)(8)(i)]

  -- if they are used for legitimate decommissioning activities that are consistent with the definition of decommissioning in 10 CFR 50.2

  -- if they do not reduce the value of the decommissioning trust below an amount necessary to place and maintain the reactor in a safe storage condition if unforeseen expenses or conditions arise

  -- if they do not inhibit the ability of the licensee to complete funding of any shortfalls in the decommissioning trust needed to ensure the availability of funds to ultimately release the site and terminate the license.

- the amount of funds available to the licensee, which varies depending on the stage of decommissioning [10 CFR 50.82(a)(8)(ii)(iii)]

  -- initially, 3 percent of the generic amount specified in 10 CFR 50.75 may be used for decommissioning planning

  -- an additional 20 percent may be used 90 days after the NRC has received the PSDAR

-- remaining funds can be used following submittal of the site-specific decommissioning cost estimate, which is required within 2 yrs following permanent cessation of operation

- submittal of the license termination plan [10 CFR 50.82(a)(9)] and the termination of the license [10 CFR 50.82(a)(11)].

10 CFR 50.36, Technical Specifications

10 CFR 50.36(c)(6) describes requirements for technical specifications specific to decommissioning. However, the requirements of 10 CFR 50.36(a), (b) and (c) still remain applicable, as modified by paragraph (c)(6). For example, a decommissioning licensee should still evaluate paragraphs (c)(1) thru (5) regarding safety limits, limiting safety-system settings, limiting control settings, limiting conditions for operation, surveillance requirements, design features, and administrative controls; (c)(7) regarding initial notification reports; and (c)(8) regarding written reports. This is reflected by the requirement of 10 CFR 50.36(e), which states that the "provisions of this section apply to each nuclear reactor licensee whose authority to operate the reactor has been removed by license amendment, order, or regulations."

10 CFR 50.48, Fire Protection

10 CFR 50.48(f) requires that licensees of permanently shutdown nuclear power plants maintain a fire-protection program to address the potential for fires that could result in the release or spread of radioactive materials.

10 CFR 50.59, Changes, Tests, and Experiments

This section allows licensees to make changes to facilities undergoing decommissioning using these requirements.

10 CFR 50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

The maintenance rule (10 CFR 50.65) requires monitoring the performance or condition of structures, systems, or components (SSCs). For licensees that have permanently ceased operation, this section applies only to the extent that the licensee shall monitor the performance or condition of SSCs associated with the storage, control, and maintenance of spent fuel. The number of SSCs within the maintenance rule program at a decommissioning facility will be significantly less than that at an operating facility.

10 CFR 50.68, Criticality Accident Requirements

This section describes the requirements that are used in lieu of maintaining a monitoring system capable of detecting a criticality in the spent fuel pool, as described in 10 CFR 70.24.

10 CFR 50.71, Inspection

This section describes the maintenance of records and making of reports. Although all paragraphs of this section are applicable, one difference between an operating facility and one being decommissioned is the requirement to update the final safety analysis report, or equivalent. As described in 10 CFR 50.71(e)(4), the decommissioning requirement is for revisions to be filed every 24 months.

10 CFR 50.73, Licensee Event Reporting System

Licensees are still required to submit a licensee event report for specific events described in the regulations within 60 days after discovery of the event. This includes airborne or liquid-effluent releases at specific levels above the concentrations in Appendix B to 10 CFR Part 20.

10 CFR 50.75, Reporting and Recordkeeping for Decommissioning Planning

Reporting and recordkeeping require that subsequent revisions updating the licensing basis must be filed with the NRC at least every 24 months by nuclear power facilities that have certified permanent cessation of operation and permanent removal of fuel for decommissioning planning. This regulation, in part, discusses how the licensee will provide reasonable assurance that funds will be available for decommissioning of the nuclear reactor.

L.1.3 10 CFR Part 71, Packaging and Transportation of Radioactive Material

Requirements for packaging, preparation for shipment, and transportation of licensed (radioactive) material are provided in these regulations. In addition, these regulations refer to the regulations of the Department of Transportation given in Title 49 of the Code of Federal Regulations.

L.1.4 10 CFR Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste

The regulations in 10 CFR Part 72 contain requirements, procedures, and criteria for the issuance of licenses to receive, transfer, and possess power-reactor spent fuel, power-reactor-related Greater-than-Class-C (GTCC) Waste, and other radioactive materials associated with spent fuel storage in an independent spent fuel storage installation and the terms and conditions under which the Commission will issue these licenses. The regulations also establish requirements, procedures, and criteria for the issuance of licenses to the U.S. Department of Energy (DOE) to receive, transfer, package, and possess power-reactor spent fuel, high-level radioactive waste, power-reactor-related GTCC waste, and other radioactive materials associated with the storage of these materials in a monitored retrievable storage installation. Finally, these regulations also establish requirements, procedures, and criteria for the issuance of Certificates of Compliance approving spent fuel storage cask designs.

L.2 Federal Statutes

Following are examples of major laws, regulations, and other requirements that may be applicable to decommissioning and environmental evaluations that occur during the decommissioning process.

American Indian Religious Freedom Act of 1978 (42 USC 1996): This act reaffirms Native American religious freedom under the First Amendment and sets United States policy to protect and preserve the inherent and constitutional right of American Indians to believe, express, and exercise their traditional religions. The act requires that Federal actions avoid interfering with access to sacred locations and traditional resources that are integral to the practice of religions.

Archaeological Resource Protection Act, as amended (16 USC 470aa et seq.): This Act requires a permit for any excavation or removal of archaeological resources from public or Indian lands. Excavations must be undertaken for the purpose of furthering archaeological knowledge in the public interest, and resources removed are to remain the property of the United States. Consent must be obtained from the Indian tribe owning lands on which a resource is located before issuance of a permit, and the permit must contain terms or conditions requested by the tribe.

Atomic Energy Act of 1954, as amended (42 USC 2011 et seq.): The Atomic Energy Act of 1954 authorizes NRC to regulate the Nation's civilian use of by-product, source, and special nuclear materials to ensure adequate protection of the public health and safety and the

DOE to establish standards to protect health or minimize dangers to life or property with respect to activities under its jurisdiction. The Atomic Energy Act and the Reorganization Plan No. 3 of 1970 [5 USC (app. at 1343)] and other related statutes gave the U.S. Environmental Protection Agency (EPA) responsibility and authority for developing generally applicable environmental standards for protection of the general environment from radioactive material. The EPA has promulgated several regulations under this authority.

Bald and Golden Eagle Protection Act, as amended (16 USC 668-668d): The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Section 668, 668c). A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations.

Clean Air Act, as amended (42 USC 7401 et seq.): The Clean Air Act, as amended, is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Clean Air Act, as amended, requires that each Federal agency, such as DOE, with jurisdiction over any property or facility that might result in the discharge of air pollutants, comply with "all Federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution. The Act requires the EPA to establish National Ambient Air Quality Standards as necessary to protect public health, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 USC 7409). The Act also requires establishing national standards of performance for new or modified stationary sources of atmospheric pollutants (42 USC 7411) and requires specific emission increases to be evaluated so as to prevent a significant deterioration in air quality (42 USC 7470). Hazardous air pollutants, including radionuclides, are regulated separately (42 USC 7412). Air emissions are regulated by the EPA in 40 CFR Parts 50 through 99. In particular, radionuclide emissions and hazardous air pollutants are regulated under the National Emission Standard for Hazardous Air Pollutants Program (see 40 CFR Parts 61 and 63).

Clean Water Act, as amended (33 USC 1251 et seq.): The Clean Water Act, which amended the Federal Water Pollution Control Act, was enacted to "restore and maintain the chemical, physical and biological integrity of the Nation's water." The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Clean Water Act, as amended, requires all branches of the Federal government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, State, interstate, and local requirements. In addition to setting water quality standards for the nation's waterways, the Clean Water Act supplies guidelines and limitations for effluent discharges from point-source discharges and provides authority for the EPA to implement the National Pollutant Discharge Elimination System (NPDES) permitting program. The NPDES program is administered by the Water Management Division of the EPA pursuant to regulations in 40 CFR Part 122 et seq.

Sections 401 and 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act Section 402(p) requires that the Environmental Protection Act establish regulations for issuing permits for stormwater discharges associated with industrial activity. Stormwater discharges associated with industrial activity are permitted through the NPDES. General Permit requirements are published in 40 CFR Part 122.

Emergency Planning and Community Right-to-Know Act of 1986 (42 USC 11001 et seq.) (also known as SARA Title III): Under Subtitle A of this Act, Federal facilities provide various information (such as inventories of specific chemicals used or stored and releases that occur from these sites) to the State Emergency Response Commission and to the Local Emergency Planning Committee to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. Implementation of the provisions of this Act began voluntarily in 1987, and inventory and annual emissions reporting began in 1988, based on 1987 activities and information. The requirements for this Act were promulgated by the EPA in 40 CFR Parts 350 through 372.

Endangered Species Act, as amended (16 USC 1531 et seq.): The Endangered Species Act, as amended, is intended to prevent the further decline of endangered and threatened species and to restore these species and their habitats. The Act is jointly administered by the U.S. Departments of Commerce and the Interior. Section 7 of the Act requires consultation with the U.S. Fish and Wildlife Service to determine whether endangered and threatened species or their critical habitats are known to be in the vicinity of the proposed action.

Migratory Bird Treaty Act, as amended (10 USC 703 at seq.): The Migratory Bird Treaty Act, as amended, is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. The Act stipulates that it is unlawful at any time, by any means, or in any manner to "kill ... any migratory bird." Although no permit is required under the Act, Federal agencies are required to consult with the U.S. Fish and Wildlife Service regarding impacts to migratory birds and to evaluate ways to avoid these effects in accordance with the U.S. Fish and Wildlife Service Mitigation Policy.

Native American Grave Protection and Repatriation Act of 1990 (25 USC 3001): This law directs the Secretary of Interior to guide responsibilities in repatriation of Federal archaeological collections and collections held by museums receiving Federal funding that are culturally affiliated to Native American tribes. Major actions to be taken under this law include (a) establishing a review committee with monitoring and policy-making responsibilities, (b) developing regulations for repatriation, including procedures for identifying lineal descent or cultural affiliation needed for claims, (c) overseeing of museum programs designed to meet the inventory requirements and deadlines of this law, and (d) developing procedures to handle unexpected discoveries of graves or grave goods during activities on Federal or tribal land.

National Environmental Policy Act of 1969 as amended (42 USC 4321 et seq.): The National Environmental Policy Act (NEPA) establishes a national policy promoting awareness of the environmental consequences of the activity of humans on the environment and promoting consideration of the environmental impacts during the planning and decisionmaking stages of a project. NEPA requires all agencies of the Federal government to prepare a detailed statement on the environmental effects of proposed major Federal actions that may significantly affect the quality of the human environment. The environmental document should discuss reasonable alternatives to the proposed action and their potential environmental consequences in accordance with the Council on Environmental Quality regulations for implementing the procedural provisions of the NEPA Implementing Procedures (40 CFR Parts 1501 through 1508) and NRC implementing regulations (10 CFR Part 51).

National Historic Preservation Act, as amended (16 USC 470 et seq.): The National Historic Preservation Act, as amended, provides that sites with significant national historic value be placed on the *National Register of Historic Places.* There are no permits or certifications required under the Act. However, if a particular Federal activity may impact a historic property resource, consultation with the Advisory Council on Historic Preservation will generally generate a Memorandum of Agreement, including stipulations that must be followed to minimize adverse impacts. Coördinations with the State Historic Preservation officer are also undertaken to ensure that potentially significant sites are properly identified and appropriate mitigative actions are implemented. These regulations are included in 36 CFR Part 800. 10 CFR Part 63 contains guidance by which historic properties are evaluated and determined eligible for listing on the National Register.

Noise Control Act of 1972, as amended (42 USC 4901 et seq.): Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies to carry out "to the fullest extent within their authority" programs within their jurisdictions in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare.

Nuclear Waste Policy Act of 1982, as amended (42 USC 10101): The Act authorizes the Federal agencies to develop a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste. The Act specifies the process for selecting a repository site and constructing, operating, closing, and decommissioning the repository. The Act also establishes programmatic guidance for these activities, including guidance to the NRC regarding the adoption of DOE's EIS for the proposed repository.

Occupational Safety and Health Act of 1970, as amended (29 USC 651 et seq.): The Occupational Safety and Health Act establishes standards to enhance safe and healthful working conditions in places of employment throughout the United States. The Act is administered and enforced by the Occupational Safety and Health Administration, a U.S. Department of Labor agency. While the Occupational Safety and Health Administration and the EPA both have a mandate to reduce exposures to toxic substances, the Occupational Safety and Health Administration's jurisdiction is limited to safety and health conditions that exist in the workplace environment. In general, under the Act, it is the duty of each employer to furnish all employees a place of employment free of recognized hazards likely to cause death or serious physical harm. Employees have a duty to comply with the occupational safety and health standards and all rules, regulations, and orders issued under the Act. Occupational Safety and Health Administration regulations (published in Title 29 of the Code of Federal Regulations) establish specific standards telling employers what must be done to achieve a safe and healthful working environment.

Pollution Prevention Act of 1990 (42 USC 13101 et seq.): The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, followed sequentially by environmentally safe recycling, treatment, and disposal. Disposal or releases to the environment should only occur as a last resort.

Resource Conservation and Recovery Act, as amended (42 USC 6901 et seq.): The treatment, storage, or disposal of hazardous and nonhazardous waste is regulated under the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984. Pursuant to Section 3006 of the Act, any State that seeks to administer and enforce a hazardous waste program pursuant to the Resource Conservation and Recovery Act may apply for EPA authorization of its program. The EPA regulations implementing the Resource Conservation and Recovery Act are found in 40 CFR Parts 260 through 280. These regulations define hazardous wastes and specify hazardous waste transportation, handling, treatment, storage, and disposal requirements.

The regulations imposed on a generator or a treatment, storage, and/or disposal facility vary according to the type and quantity of material or waste generated, treated, stored, and/or disposed of. The method of treatment, storage, and/or disposal also impacts the extent and complexity of the requirements.

Safe Drinking Water Act, as amended (42 USC 300 [F] et seq.): The primary objective of the Safe Drinking Water Act, as amended, is to protect the quality of the public water supplies and all sources of drinking water. The implementing regulations, administered by the EPA unless delegated to the states, establish standards applicable to public water systems. They promulgate maximum contaminant levels, including those for radioactivity, in public water systems, which are defined as public water systems that serve at least 15 service connections used by year-round residents or regularly serve at least 25 yr-round residents. Safe Drinking Water Act requirements have been promulgated by the EPA in 40 CFR Parts 100 through 149. For radionuclides, the regulations in effect now specify that the average annual concentration of beta particle and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 0.004 rem (4 millirem) per year. The maximum contaminant level for gross alpha particle activity is 15 picocuries per liter. The EPA proposed revisions to limits on regulating radionuclides on July 18, 1991. The proposed rule has not been finalized, and the more conservative standards were used for purposes of analysis. Other programs established by the Safe Drinking Water Act include the Sole Source Aquifer Program, the Wellhead Protection Program, and the Underground Injection Control Program.

<u>Toxic Substances Control Act (15 USC 2601 et seq.)</u>: The Toxic Substances Control Act provides the EPA with the authority to require testing of chemical substances, both new and old, entering the environment and regulates them where necessary. The law complements and expands existing toxic substance laws such as §112 of the Clean Air Act and §307 of the Clean Water Act. The Toxic Substances Control Act came about because there were no general Federal regulations for the potential environmental or health effects of the thousands of new chemicals developed each year before they were introduced into the public or commerce. The Toxic Substances Control Act also regulates the treatment, storage, and disposal of toxic substances, specifically polychlorinated biphenyls, chlorofluorocarbons, asbestos, dioxins, certain metal-working fluids, and hexavalent chromium. The asbestos regulations under the Toxic Substances Control Act were ultimately overturned. However, regulations pertaining to asbestos removal, storage, and disposal are promulgated through the National Emission Standard for Hazardous Air Pollutants Program (40 CFR Part 61, Subpart M). For chlorofluorocarbons, Title VI of the Clean Air Act Amendments of 1990 requires a reduction of chlorofluorocarbons beginning in 1991 and prohibits production beginning in 2000.

L.3 Executive Orders

During the history of NEPA implementation, a number of Executive Orders have been issued that may be applicable to environmental evaluation during the decommissioning process. The following provides a short summary of some of these Orders.

<u>Executive Order 11988 (Floodplain Management)</u>: Directs Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain and that floodplain impacts be avoided to the extent practicable.

Executive Order 11990 (Protection of Wetlands): Directs government agencies to avoid, to the extent practicable, any short- and long-term adverse impacts on wetlands wherever there is a practicable alternative.

Executive Order 12898 (Environmental Justice): Directs Federal agencies to achieve environmental justice by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions. The Order creates an Interagency Working Group on Environmental Justice and directs each Federal agency to develop strategies within prescribed time limits to identify and address environmental justice concerns. The Order further directs each Federal agency to collect, maintain, and analyze information on the race, national origin, income level, and other readily accessible and appropriate information for areas surrounding facilities or sites expected to have a substantial environmental, human health, or economic effect on the surrounding populations, when such facilities or sites become the subject of a substantial Federal environmental administrative or judicial action and to make such information publicly available.

Executive Order 13007 (Indian Sacred Sites): Directs Federal agencies to accommodate, to the extent practicable, access to and ceremonial use of Indian sacred sites by Indian religious practitioners, and avoid adversely affecting the physical integrity of these sites.

Appendix M

Glossary

Appendix M

Glossary

Absorbed dose The amount of radiation energy absorbed, especially by human tissue; measured in rads.

Absorption The process of taking in, as when a sponge takes up water. Chemicals can be absorbed through the skin into the bloodstream and then transported to other organs. Chemicals can also be absorbed into the bloodstream after breathing or swallowing.

Acute Occurring over a short time, usually a few minutes or hours. An acute effect happens within a short time after exposure. An acute exposure can result in short-term or long-term health effects. See Chronic.

ALARA Acronym for "as low as reasonably achievable," i.e., making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken and taking into account the state of technology, the economics of technological improvements and of the benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. See 10 CFR 20.1003.

Alpha particle A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particle will generally fail to penetrate the dead layers of cells covering the skin and can be easily stopped by a sheet of paper. Alpha particles are hazardous when an alpha-emitting isotope is inside the body.

Ambient — Surrounding. Ambient air is usually outdoor air (as opposed to indoor air).

Aquifer — An underground source of water geologically contained in a layer of rock, sand, or gravel.

Background level — A typical or average level of a chemical or element in the environment. Background often refers to naturally occurring or uncontaminating levels.

Background radiation — Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. It does not include radiation from source, by-product, or special nuclear materials regulated by the Nuclear Regulatory Commission (NRC). The typically quoted U.S. average individual exposure from background radiation is 360 mrem per yr.

Becquerel (Bq) — The unit of radioactive decay equal to 1 disintegration per second. 37 billion (3.7×10^{10}) Bq = 1 curie (Ci).

Beta particle — A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns. Beta-emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets of metal or plastic.

Boiling water reactor (BWR) — A reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be used directly to drive a turbine and electrical generator, thereby producing electricity.

By-product material — Any radioactive material, tailings or wastes (except special nuclear material) that is 1) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or using special nuclear material (as in a reactor) and 2) produced by the extraction or concentration of uranium or thorium from ore. See 10 CFR 20.1003.

Calibration — The adjustment, as necessary, of a measuring device such that it responds within the required range and accuracy to known values of input.

Certified fuel-handler — A nonlicensed operator who is qualified in accordance with a fuel-handler training program approved by the NRC.

Chronic — Occurring over an extended period of time, e.g., several weeks, months, or years. See Acute.

Committed dose equivalent (CDE) — This is the dose to some specific organ or tissue that is received from an intake of radioactive material by an individual during the 50-yr period following the intake. See 10 CFR 20.1003.

Committed effective dose equivalent (CEDE) — The sum of the committed dose equivalents for a given organ or tissue multiplied by a weighting factor (W_t) expressed in units of sieverts (Sv) or rems. See 10 CFR 20.1003.

Compact — A group of two or more States formed to dispose of low-level radioactive waste on a regional basis. Forty-two States have formed nine compacts.

Contamination — Undesired radioactive material or residual radioactivity that is deposited on the surface of or inside structures, areas, objects or people in excess of acceptable levels (e.g., for a release of a site or facility for unrestricted use).

Curie (Ci) — The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37-billion (3.7×10^{10}) disintegrations per second, which is approximately the activity of 1 gram of radium. A curie is also a quantity of any radionuclide that decays at a rate of

37-billion disintegrations per second. It is named for Marie Curie, who discovered radium in 1898.

Decommission (decommissioning) The process of safely removing a facility from service followed by reducing residual radioactivity to a level that permits termination of the NRC license. See 10 CFR 20.1003.

DECON An option for decommissioning in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits termination of the license shortly after cessation of operations.

Decontamination The reduction or removal of contaminated radioactive material from a structure, area, object, or person. See 10 CFR 20.1003 and 20.1402.

Dermal Referring to the skin. For example, dermal absorption means absorption through the skin.

Disproportionately high and adverse environmental effects When determining whether environmental effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable:
(a) whether there is or will be an impact on the natural or physical environment that significantly (as used by NEPA) and adversely affects a minority population, low-income population, or Indian tribe - Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian tribes when those impacts are interrelated to impacts on the natural or physical environment,
(b) whether environmental effects are significant (as employed by NEPA) and are or may be having an adverse impact on minority populations, low-income populations, or Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group, and (c) whether the environmental effects occur or would occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environ-

mental hazards.

Disproportionately high and adverse human health effects

When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) whether the health effects, which may be measured in risks and rates, are significant (as used by NEPA), or above generally accepted norms (adverse health effects may include bodily impairment, infirmity, illness, or death), (b) whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian tribe to an environmental hazard is significant (as employed by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group, and (c) whether health effects occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards.

Dose equivalent (dose)

The product of absorbed dose in tissue multiplied by a quality factor, and then sometimes multiplied by other necessary modifying factors at the location of interest. It is expressed numerically in rems or sieverts. See 10 CFR 20.1003.

Dosimeter

A portable instrument (e.g., a film badge, thermoluminescent, or pocket dosimeter) worn by plant personnel for measuring and recording the total accumulated dose of ionizing radiation.

Dosimetry

The theory and application of the principles and techniques involved in the measurement and recording of ionizing radiation doses.

Effective half-life

The time required for a radionuclide contained in a biological system, such as a human or an animal, to reduce its activity by one-half as a combined result of radioactive decay and biological elimination.

ENTOMB	A method of decommissioning in which radioactive structures, systems, and components are encased in a structurally long-lived material, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.
Exposure	Contact with a chemical or element by swallowing, breathing, or direct contact (such as through the skin or eyes). Exposure may be either short-term (acute) or long- term (chronic).
External radiation	Exposure to ionizing radiation when the radiation source is located outside the body.
Fissile material	Any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239. Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning.
Fission (fissioning)	The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.
Fission gases	Those fission products that exist in the gaseous state. In nuclear power reactors, this includes primarily the noble gases, such as krypton and xenon.
Fission products	The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclide formed by the fission fragments' radioactive decay.
Fissionable material	Commonly used as a synonym for fissile material, the meaning of this term has been extended to include material that can be fissioned by fast neutrons, such as uranium-238.

Fuel assembly
A cluster of fuel rods (or plates). Also called a fuel element. A reactor core is made up of many fuel assemblies.

Fuel cycle
The series of steps involved in supplying fuel for nuclear power reactors. It can include mining, milling, isotopic enrichment, fabrication of fuel elements, use in a reactor, chemical reprocessing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material, refabrication into new fuel elements, and waste disposal.

Fuel rod
A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are assembled into bundles called fuel elements or fuel assemblies, which are loaded individually into the reactor core.

Fusion reaction
A reaction in which at least one heavier, more stable nucleus is produced from two lighter, less stable nuclei. Reactions of this type are responsible for enormous releases of energy, e.g., in the energy of stars.

Gamma radiation
High-energy, short wave-length, electromagnetic radiation emitted from the nucleus. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium. Gamma rays are similar to x-rays.

Graphite
A form of carbon, similar to the lead used in pencils, used as a moderator in some nuclear reactors.

Greenfield
One possible end state of decommissioning in which above-ground structures have been removed and efforts made to revegetate the site. Buildings may have been removed to below-grade and then covered with soil. NRC decommissioning regulations do not require a greenfield end state.

Groundwater

The supply of fresh water found beneath the earth's surface (usually in aquifers) that is often used for supplying wells and springs.

Hazardous waste

By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

High decommissioning activity (HDA)

The licensee is actively dismantling, decontaminating, or performing activities that contribute to site release or license termination. Includes, but is not limited to, (1) major decommissioning activities or (2) periods of decommissioning in which the aggregate of licensee activities represents a significant change in facility configuration, increase in occupational dose, curies relocated, or decommissioning cost expenditure.

Highly enriched uranium

Uranium enriched to 20 percent or greater in the isotope Uranium-235.

High-level waste (HLW)

Consists of (1) irradiated (spent) reactor fuel, (2) liquid waste resulting from the operation of the first cycle solvent extraction system, and the concentrated wastes from subsequent extraction cycles, in a facility for reprocessing irradiated reactor fuel, or (3) solids into which such liquid wastes have been converted. Primarily in the form of spent fuel discharged from commercial nuclear power reactors, HLW also includes some reprocessed HLW from defense activities, and a small quantity of reprocessed commercial HLW. See Low-level waste and Radioactive waste.

High radiation area

Any area with dose rates greater than 1 mSv (100 mrems) in 1 hour, 30 centimeters from the source or from any surface through which the ionizing radiation penetrates. Areas at licensee facilities must be posted as "high radiation areas" and access into these areas is maintained under strict control.

Hot spot The region in a radiation/contamination area in which the level of radiation/contamination is significantly greater than in neighboring regions in the area.

Ingestion Swallowing (such as eating or drinking). Ingestion of radioactive material or other contaminants can occur via contact with contaminated food, drink, utensils, cigarettes, hands, or other surfaces. After ingestion, chemicals can be absorbed into the blood and distributed throughout the body.

Inhalation Breathing. Exposure may occur from inhaling contaminants because they can be deposited in the lungs, taken into the blood, or both.

Ion (1) An atom that has too many or too few electrons, causing it to have an electrical charge, and, therefore, be chemically active (2) An electron that is not associated (in orbit) with a nucleus.

Ionizing radiation Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Some examples are alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Independent spent fuel storage installation (ISFSI) A complex designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. The most common design for an ISFSI at this time is a concrete pad with dry casks containing spent fuel bundles.

Industrial use area An area that has been designated appropriate for industrial activities.

Irradiation Exposure to radiation.

Isotope One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Thus, carbon-12, carbon-13, and carbon-14 are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but often different physical properties (for example, carbon-12 and carbon-13 are stable, whereas carbon-14 is radioactive).

Leaching

Residual contamination transported into the subsurface as water trickles through soils or materials that contain the contamination. The water can carry the contamination through the soil and pollute nearby groundwater or surface water.

License termination plan

The license termination plan is a document that is required by 10 CFR 50.82(a)(9). The license termination plan, submitted by the licensee at least 2 yrs before termination of the license, addresses the following items: site characterization, identification of remaining site dismantlement activities, plans for site remediation, detailed plans for final radiation surveys for release of the site, method for demonstrating compliance with the radiological criteria for license termination, updated site-specific estimate of remaining decommissioning costs, and supplement to the environmental report pursuant to 10 CFR 51.53(d). The license termination plan approval process is by license amendment.

Licensing basis

The set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The licensing basis includes the NRC regulations and appendixes, orders, license conditions, exemptions, and technical specifications. It also includes the plant-specific design-basis information defined in 10 CFR 50.2, as documented in the most recent final safety analysis report (as required by 10 CFR 50.71) and the licensee's commitments remaining in effect that were made in docketed licensing correspondence, such as licensee responses to NRC bulletins, generic letters, and enforcement actions, required certifications and submittals, NRC safety evaluations, and licensee event reports.

Light water reactor (LWR) A term used to describe reactors using ordinary water as coolant, including boiling water reactors (BWRs) and pressurized water reactors (PWRs), the most common types used in the United States.

Low decommissioning activity (LDA) Periods of decommissioning when a licensee either (1) maintains their facility in a true SAFSTOR configuration or (2) incrementally dismantles, decontaminates, or decommissions structures, systems, or components at such a low rate or small volume that there are only trivial changes to facility configuration, occupational dose, curie relocation, or decommissioning cost expenditure.

Low-income population Low-income populations in an affected area should be identified with the annual statistical poverty thresholds from the Bureau of the Census' Current Population Reports, Series P-60 on Income and Poverty. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a set of individuals (e.g., migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect.

Low-level waste (LLW) A general term for a wide range of wastes. Industries, hospitals, research institutions, private or government laboratories, and nuclear fuel-cycle facilities (e.g., nuclear power reactors and fuel fabrication plants) using radioactive materials generate LLW as part of their normal operations. These wastes are generated in many physical and chemical forms and levels of contamination. LLW usually comprises the following material contaminated with radionuclides: rags, papers, filters, solidified liquids, ion-exchange resins, tools, equipment, discarded protective clothing, dirt, construction rubble, concrete, or piping. See High-level waste and Radioactive waste.

Major decommissioning activity	For a nuclear power facility, any activity that results in permanent removal of major radioactive components, permanently modifies the structure of the containment (for PWRs, the primary containment; for BWRs, the primary and secondary containments), or results in the dismantling of components or systems for shipment containing "greater than Class C" waste (10 CFR 61.55). The licensee is precluded by regulation from conducting major decommissioning activities until 90 days after the NRC has received the Post-Shutdown Decommissioning Activities Report and the 10 CFR 50.82(a)(1) certifications have been submitted.
Major radioactive component	For a nuclear power plant, this includes the reactor vessel and internals, steam generators, pressurizer, large-bore reactor coolant system piping, and other large components that are radioactive to a comparable degree.
MARSSIM	The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), which provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with dose- or risk-based regulation. The MARSSIM guidance focuses on the demonstration of compliance during the final status survey following scoping, characterization, and any necessary remedial actions.
Media	Soil, water, air, plants, animals, or any other parts of the environment that can contain contaminants. Body tissues or fluids such as blood, bone or urine may also be media. The singular of "media" is "medium."
Minority	Individuals who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.
Minority population	According to the CEQ, minority populations should be identified where either (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully

greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a geographically dispersed/transient set of individuals (e.g., migrant workers or Native American), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as not to artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds. NRR adopted a standard of 20 percentage points as "meaningfully greater."

Mixed waste Mixed radioactive and hazardous waste (mixed waste). (EPA 1997)

Nuclear energy The energy liberated by a nuclear reaction (fission or fusion) or by radioactive decay.

Nuclear island The nuclear island concept is used during decommissioning as a model for reducing the focus of the safeguards and security systems to the location where the fuel is being stored. For example, if the fuel is being stored in the spent fuel pool, the focus of the safeguards are on protection of only the spent fuel pool building and not the balance of the plant.

Nuclear waste See High-level waste and Low-level waste.

Operational Area The portion of the plant site where most or all of the site activities occur, such as reactor operations, materials and equipment storage, parking, substation operation, facility service and maintenance, etc. This includes all areas within the protected area fence, the intake and discharge structures, the cooling system, and other site structures, as well as associated paved, graveled, and maintained landscaped areas.

Partial site release

The release of a portion of an operating or decommissioning nuclear power reactor facility site for unrestricted use. The licensee maintains a license for the remainder of the site. At this time there is a proposed rulemaking to change the regulations to specifically address the criteria for a partial site release. The rulemaking ensures that any remaining residual radioactivity from licensed activities in parts of a site released fro unrestricted use will meet the radiological criteria for license termination. For more detail, see the text in Chapter 3.

Permanent cessation of power operations

The permanent cessation of power operations is a licensee determination certified to the NRC in writing in accordance with 10 CFR 50.82(a)(1)(i). Following this certification, the licensee would possess the power reactor structures, systems, and components, site, and related radioactive material, but be prohibited by regulation from operating the reactor.

Personnel monitoring

The use of portable survey meters to determine the amount of contamination on an individual, or the use of dosimetry to determine an individual's occupational radiation dose.

Possession-only license (POL)

A name for the license retained by a 10 CFR Part 50 licensee that was amended to reflect the permanent shutdown condition of the facility and the licensee's continued possession of nuclear fuel.

Post-operational phase

The interval between the final reactor shutdown and the licensee's certification that all fuel has been permanently removed from the reactor vessel. See 10 CFR 50.82(a)(1)(ii). During this phase, the licensee would establish safe shutdown conditions and could conduct activities to dismantle and decontaminate structures, systems, and components or place them in a storage configuration.

Post-shutdown decommissioning activities report (PSDAR)
The PSDAR is required by 10 CFR 50.82(a)(4). The licensee is required to submit a PSDAR to the NRC within two yrs after permanent cessation of operations. Includes a description of the planned decommissioning activities, a schedule for the completion of these activities, an estimate of expected costs, and a discussion that provides the reasons for concluding that the environmental impacts associated with the site-specific decommissioning activities will be bounded by appropriate environmental impact statements previously issued.

Pressurized water reactor (PWR)
A power reactor in which heat is transferred from the core to an exchanger by high-temperature water kept under high pressure in the primary system. Steam is generated in a secondary circuit. Many reactors producing electric power are PWRs.

Previously disturbed area
An area that has been physically moved, uncovered, destabilized, or otherwise modified from its undisturbed natural condition. This definition excludes areas restored to a natural state, such that vegetative ground cover and soil characteristics that are similar to adjacent or nearby natural conditions.

Quality assurance and quality control (QA/QC)
A system of procedures, checks, and audits to judge the quality of measurements and reduce the uncertainty of environmental data.

Rad
The special unit for radiation absorbed dose, which is the amount of energy from any type of ionizing radiation (e.g., alpha, beta, gamma, neutrons, etc.) deposited in any medium (e.g., water, tissue, air). A dose of 1 rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing tissue. 100 rad = 1 gray.

Radiation
Particles (alpha, beta, neutrons) or photons (gamma) emitted from the nucleus of unstable radioactive atoms as a result of radioactive decay.

Radiation standards Exposure standards, permissible concentrations, rules for safe handling, regulations for transportation, regulations for industrial control of radiation, and control of radioactive material by legislative means.

Radioactive contamination Deposition of radioactive material in any place where it may harm persons or equipment.

Radioactive waste Solid, liquid, and gaseous materials from nuclear operations that are radioactive or become radioactive and for which there is no further use. Wastes are generally classified as high-level (having radioactivity concentrations of hundreds of thousands of curies per gallon or foot), low-level (in the range of 1 microcurie per gallon or foot), or intermediate level (between these extremes). See 10 CFR Parts 60 and 61.

Radioactivity The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. Also, the rate at which radioactive material emits radiation. Measured in units of becquerels or disintegrations per second.

Radioisotope An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5000 natural and artificial radioisotopes have been identified.

Radiologically non-impacted Areas that have no reasonable potential for radioactive residual contamination are classified as non-impacted by MARSSIM (NRC 1997).

Radiological waste See "radioactive waste."

Radionuclide A radioisotope.

Reactor A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. The varieties are many, but all incorporate features, such as fissionable material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a reflector to conserve escaping neutrons, provisions for removal of heat, measuring and controlling instruments, and protective devices. The reactor is the heart of a nuclear power plant.

Real property Includes land, improvements on the land, or both, including interests therein. All equipment or fixtures (e.g., plumbing, electrical, heating, built-in cabinets, and elevators) that are installed in a building in more or less permanent manner or that are essential to its primary purpose.

Reference man A hypothetical person with the anatomical and physiological characteristics of an average individual, used in calculations assessing internal dose (also may be called "standard man").

rem A conventional standard unit that measures the effects of ionizing radiation on humans. The international system (SI) equivalent unit is the sievert.

Restricted use A category of use of the facility after license termination. In restricted use, a licensee has demonstrated that further reductions in residual radioactivity would result in net public or environmental harm or that residual levels are as low as reasonably achievable, and that the licensee has made provisions for legally enforceable institutional controls (e.g., restrictions placed in the deed for the property describing what the land can and cannot be used for) that provide reasonable assurance that the radiological criteria set by the NRC will not be exceeded. In addition, the licensee must have provided sufficient financial assurance to an amenable independent third party to assume and carry out responsibilities for any necessary control and maintenance of the site. There are also regulations relating to the documentation of how the advice of individuals and institutions in the community who may be affected by the decommissioning has been sought and incorporated in the license termination plan related to decommissioning by unrestricted use.

Risk	The probability of harm. For example, for a person who has measles, the risk of death is one in one million.
Roentgen (R)	A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.
Rubblization	The demolition of onsite concrete structures. Rubblizing these structures could result in material ranging from gravels to large concrete blocks, or a mixture of both.
Safety limit	A limit placed upon important process variables that are found to be necessary to reasonably protect the integrity of the physical barriers guarding against the uncontrolled release.
Safety-related structures, systems, and components	Nuclear plant structures, systems, and components that are relied upon to remain functional during and following design-basis events to ensure: • the integrity of the reactor coolant pressure boundary • the capability to shut down the reactor and maintain it in a safe shutdown condition, or • the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the applicable guideline exposures set forth in 10 CFR 50.34(a)(1) or 10 CFR 100.11.
SAFSTOR	A method of decommissioning in which the nuclear facility is placed and maintained in a safe stable condition for a number of years until it is subsequently decontaminated and dismantled to levels that permit license termination. During SAFSTOR, a facility is left intact, but the fuel has been removed from the reactor vessel and radioactive liquids have been drained from systems and components

and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during decontamination and dismantlement.

Sewage
The waste and wastewater produced by residential and commercial sources and discharged into sewers.

Sewage waste
By-products of society from sewer sources.

Sewer sludge
Sludge produces at a Publicly Owned Treatment Works, the disposal of which is regulated under the Clean Water Act.

Sievert
An international system (SI) unit that measures the effects of ionizing radiation on humans. The conventional equivalent unit is the rem.

Site characterization
One of the final steps before the termination of the license. The site characterization contains a description of (1) the radiological contamination on the site before any cleanup activities associated with decommissioning took place, (2) a historical description of site operations, spills, and accidents, and (3) a map of remaining contamination levels and contamination locations. The purpose of the site characterization is to assist in planning for remediation, selection of remediation techniques, and assessment of radiological impacts and cost estimates.

Sludge
A semi-solid residue from any of a number of air or water treatment processes; can be a hazardous waste.

Spent nuclear fuel
Depleted fuel that has been removed from a nuclear reactor because it can no longer sustain power production (cannot effectively sustain a chain reaction) for economic or other reasons.

Target organ
An organ (such as the liver or kidney) that is specifically affected by a toxic chemical.

Technical specifications (TS)	An appendix to the facility license that contains safety requirements, bases, safety limits, limiting conditions for operation, and administrative requirements to provide assurance that decommissioning can be conducted safely and in accordance with regulatory requirements. Terminology such as "defueled TSs" or "decommissioning TSs" has been used to describe technical specifications that have been amended to reflect the permanent shutdown condition of reactor.
Transfer	Includes all real estate transfers (e.g., donation, exchange, disposal, easement, lease, permit, license).
Transuranic element	An artificially made, radioactive element that has an atomic number higher than uranium in the periodic table of elements, e.g., neptunium, plutonium, americium, and others.
Transuranic waste	Material contaminated with transuranic elements that is produced primarily from reprocessing spent fuel and from use of plutonium in fabrication of nuclear weapons.
Unrestricted area	The area outside the owner-controlled portion of a nuclear facility (usually the site boundary). An area in which a person could not be exposed to radiation levels in excess of 2 mrem in any 1 hour from external sources. See 10 CFR 20.1003.
Unrestricted use	A category of facility use after license termination. Unrestricted use means that there are no restrictions on how the site may be used. The licensee is free to continue to dismantle any remaining buildings or structures, and to use the land or sell the land for any type of application.
Vapor	The gaseous form of substances that are normally in liquid or solid form.
Volatile organic compound (VOC)	An organic chemical that evaporates easily. Petroleum products such as kerosene, gasoline, and mineral spirits contain VOCs.
Weighting factor (W_t)	Multipliers of the equivalent dose to an organ or tissue used for radiation protection purposes to account for differ-

ent sensitivities of different organs and tissues to the induction of stochastic effects of radiation. See 10 CFR 20.1003.

Whole-body counter

A device used to identify and measure the radioactive material in the bodies of human beings and animals. It uses heavy shielding to keep out naturally existing background radiation and measures radiation levels with ultra sensitive radiation detectors and electronic counting equipment.

Whole-body exposure

An exposure of the body to radiation, in which the entire body, rather than an isolated part, is irradiated. Where a radioisotope is uniformly distributed throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be considered as whole-body exposure.

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11. ABSTRACT *(200 words or less)*

This document is a final supplement to the NRC Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities (GEIS), issued in 1988 as NUREG-0586. This supplement was prepared because of the technological advances in decommissioning operations, experience gained by licensees, and changes made to NRC regulations since the 1988 GEIS. It is intended to be used to evaluate environmental impacts during the decommissioning of nuclear power reactors as residual radioactivity at the site is reduced to levels that allow for termination of the NRC license. This supplement addresses only the decommissioning of nuclear power reactors licensed by the NRC. It updates the sections of the 1988 GEIS relating to pressurized water reactors, boiling water reactors, and multiple reactor stations. It goes beyond the 1988 GEIS to consider high-temperature gas-cooled reactors and the fast breeder reactors. This document can be considered a stand-alone document and the environmental impacts described herein supercede those described in the 1988 GEIS.

The scope of this supplement is based on the decommissioning activities performed to remove radioactive materials from structures, systems, and components from the time that the licensee certifies that they have permanently ceased power operations until the license is terminated. An evaluation process was developed to determine environmental impacts from the specific activities that occur during reactor decommissioning, based on data from site visits and from licensees at reactor facilities being decommissioned. The data obtained from the sites were analyzed and then evaluated against a list of variables that defined the parameters for facilities that are currently operating but which one day will be decommissioned. This evaluation resulted in a range of impacts for each environmental issue that may be used for comparison by licensees that are or will be decommissioning their facilities. The staff has considered public comments received during scoping and on the draft in preparation of this final supplement.

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